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I STOCKHOLM

FÖRHANDLINGAR

UTGIVARE

PER H. LUNDEGÅRDH

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GEOLOGISKA FÖRENINGENS I STOCKHOLM FÖRHANDLINGAR

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GEOLOGISKA FÖRENINGENS
I STOCKHOLM FÖRHANDLINGAR

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Österdalsisen av Svartisen

Av

G. LUNDQVIST

ABSTRACT

The author has visited the part of the large glacier Svartisen in Norway that is lled Österdalsisen (Fig. 1) in the years 1935 and 1960. An immense wastage during is interval has been established as illustrated by photographs. In front of the west- n tongue an ice-dammed lake was formed which in 1943 was partly drained towards e east below the ice. In 1959 this draining was made artificial by means of a tunnel the bedrock. The ice-dammed lake was filled with large ice boulders and it is erefore like the formation milieu of the ablation moraine. The author recommends continued study of the area. Some mention is given of the insignificant normal de- sits (till and sand) of the glacier.

Inledning

Tillsammans med Erik Granlund besökte jag och våra hustrur 1935 Svart- en bl. a. den del som benämnes Österdalsisen (Granlund och Lundqvist 936). Under semester i Hemavan 1960 ville jag återse samma område för att ett begrepp om avsmältningen under dessa 25 år. Hur förhållandena tett sig nder mellantiden känner jag ej, men vissa uppgifter erhölls av Sture af Eken- am i Hemavan, som följde oss på turen och Anton Svartisdal (f. d. Nielsen) i artisdalen. Sammanställda kan dessa uppgifter vara av intresse för uppfatt- ngen om några detaljer i landisens avsmältningsförlopp. Redan nu må det gas att Österdalsisens avsmältning är så betydande, att man har svårt att ldmässigt belysa den. Det är helt enkelt för stora olikheter (fig. 1). Både 935 och 1960 togs ett stort antal bilder, men det är endast sällan möjligt att en lätt iakttagbar konnexion mellan dem. Isens hopsjunkning är betydande h därför är de platser, varifrån bilderna tagits mycket olika, emedan de gam- bilderna ej tagits med i fält. Därtill kommer att det 1960 var mycket dåligt der.

Givetvis kan jag knappast lämna några exakta data på avsmältningen, men dana torde i sinom tid erhållas genom de mätningar som en engelsk expedi- n insamlade. Mina uppgifter, som närmast är av historisk och turistisk na-

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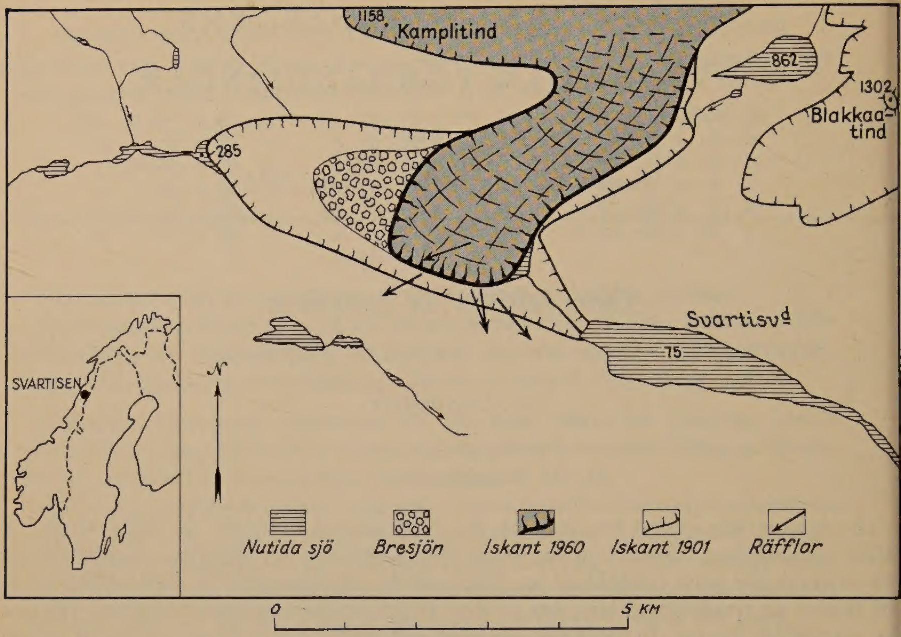


Fig. 1. Svartisens gren Österdalsisen efter Norska Topografiska kartan 1901 och min kartskiss 1960.

The branch Österdalsisen of the great glacier complex Svartisen in Norway according to the Topographica Maps of Norway and a scetch map of my own 1960.

Nutida sjö = recent lake; Bresjön = the ice-dammed lake; iskant 1960 = ice margin 1960; iskant 1901 = ice margin 1901; räfflor = striae

tur kan dock icke föregripa dessa mätningar, i all synnerhet som vårt besök omfattade endast en dag.

Den betydande förändring glaciären undergått beror på två omständigheter: 1. den normala av klimatet förorsakade och

2. den abnorma utveckling som sammanhänger med det nedan beskrivna speciella förloppet. Det är lämpligt att beskriva dem var för sig.

Den normala avsmältningen

Redan 1935 var förändringen från 1882 och 1910 betydande; det må räcka med en hänvisning till mina tidigare data (Granlund och Lundqvist, 1936 och där anförd litteratur) samt till Holmsen 1932.

Förändringen mellan 1935 och 1960 torde vara av ungefär samma storleksordning som den tidigare. Låt oss börja med istungan mot Svartisvattnet. Den gick ned i en tämligen smal spets i avloppsälvens kanjon ca 650 m från sjön 1960 hade hela denna långa tunga försvunnit så att fronten ligger nära 1,5 km från sjön. De olika delarna av dessa 850 m, som smält bort sedan 1935, ha dock varit mycket olika utformade: nedre delen smal men mäktig, övre delen relativt flack och tunn. Nu utmynnar f. ö. isen i en liten sjö dämd mellan isen och en klipptröskel i öster (fig. 2 och 3).

Det kan vara av ett visst intresse att erfara, att det var strax väster om denna lilla isdämda sjö som man tog isblocket till Albert Schweitzers sjukhus i Afrika. Det vägde 3 050 kg då och vid framkomsten till Lambarene 2 714 kg.

Mittpartiet av Österdalsisens sydfront nådde 1935 ganska nära ett litet björkbestånd, som nu tillväxt och brett ut sig väsentligt. Nu däremot syntes, så vitt jag förstår, samma björkbestånd mellan 50 och 100 m högre än iskanten. Detta är dock som synes endast en grov uppskattning.

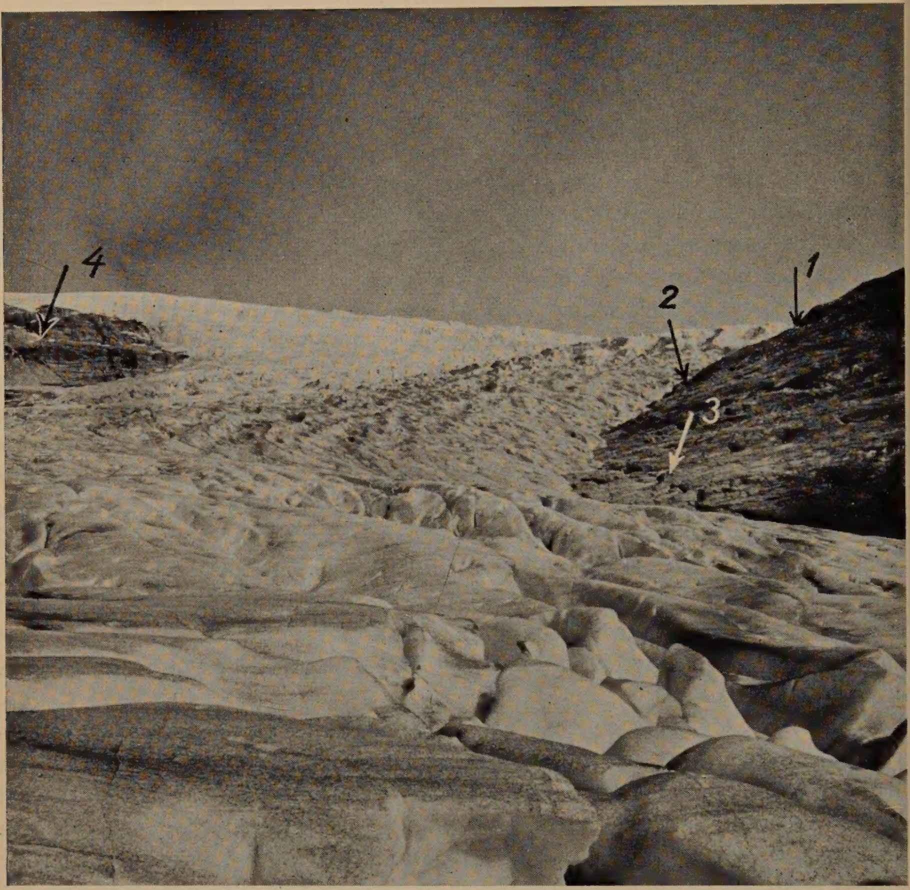
Istungans nedre del, själva Österdalsisen, har sålunda sjunkit ihop väsentligt till en flackt och oregelbundet undulerande platå. Det är därför med en viss förvåning man konstaterar, att förändringen ovan isfallet icke synes vara fullt så påfallande. På västra sidan, alltså just där Kamplitind skjuter ut som den tröskel som förorsakar isfallet, synes på mina gamla bilder en liten bäck störta sig utför branten (det finns dock flera likartade bäckar). På 1960 års bilder synes samma bäck ligga alltjämt relativt nära isen (fig. 3). Om dessa iakttagelser är riktiga — avståndet till bäcken är ca 3 km och sikten var urusel 1960 — är orsaken sannolikt följande. I ispasset mellan Kamplitind och Blakkaatind, alltså det ifrågavarande området, tränger huvudisen i norr på så kraftigt, att isen just i det smala området icke hinner undan. Det är alltså i viss mån frågan om en form av dämning här. Avsmältningsförloppet är sålunda icke fullt normalt här.

Inom västra delen av tungan är förändringarna faktiskt betydande. Hur betydande framgår med utomordentlig tydlighet av fig. 4 och 5. De är båda tagna från punkter nära iskanten, den sista alltså betydligt lägre. Horisontlinjerna blir därigenom ganska olika och skillnaden förefaller än större genom de låga regnmolnen som 1960 dolde de högsta delarna av fjället mitt emot. Det är kanske svårt att på reproduktionerna se de detaljer som utmärkes med pilarna. Nr 4 och 5 är detaljer i bäckloppet och nr 7 är ett par karakteristiska block.

Oaktat bilden 1935 togs högt upp på fjällsluttningen framför isen ser man isytan mäktigt välvande sig upp och döljande en stor del av nordsluttningens nedre parti. 1960 är situationen helt annorlunda. Då ser man t. o. m. bakom, alltså norr om istungan, där den ljusa tonen på marken anger, att densamma nyligen blivit blottad (fig. 5).

Bakom istungan till vänster ser man även den märkliga bassängen, Bresjön (den benämnes så i de norska handlingarna), som omnämnes i det följande (fig. 7). Just detta område är det som erbjuder stort intresse för fortsatta geologiska arbeten.

Det vore givetvis av intresse att erfara, hur hastig avsmältningen är i siffror uttryckt. Ovan nämndes att en engelsk expedition, British Svartisen Ice Cap Expedition 1960, låg där för observationer däröver. De hade på några ställen utmärkt iskantens läge med stora block och på den målat ifrågavarande datum »Ice Edge 1.7.60». De utvisade att avsmältningen från den angivna tiden till mitt besök 23.8. var fantastisk, varför det är med spänning man inväntar siffrornas publicering.



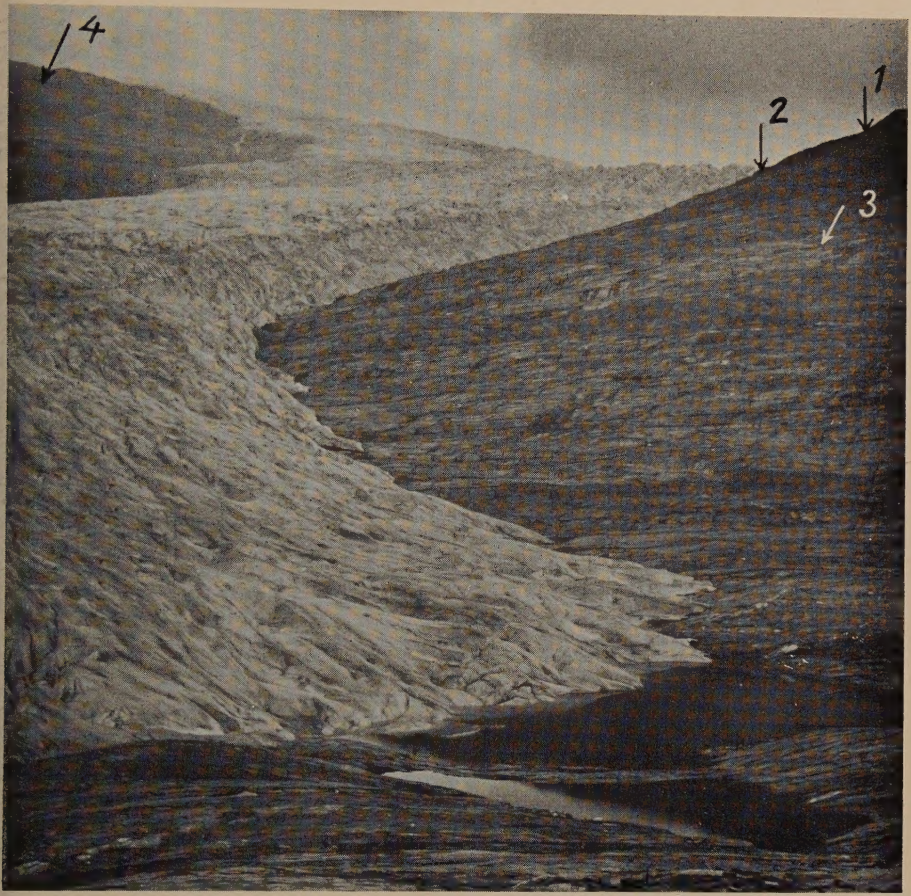
G. Lundqvist 22. 8. 1935.

Fig. 2. Östra delen av Österdalsisen 1935.
The eastern part of the Österdalsisen in 1935.

Så mycket torde jag dock våga säga utan att föregripa deras resultat som att avsmältningen är väsentligt större än de värden jag redovisade 1936. Redan då inlade jag dock däri en viss reservation därigenom att kurvan fig. 6 grundade sig på tiden 1897—1935. Den inrymde därför även eventuella framryckningar, vilka givetvis måste ha bidragit till en sänkning av värdet på den årliga avsmältningen. Denna är sannolikt koncentrerad till ett relativt kort skede per år. Holmsens (1932, s. 85) tabell visar, hur växlande glaciärernas tillväxt och avsmältning är från år till år. Jag hänvisar även till Holmsen 1949, s. 156.

Den abnorma utvecklingen

Detta kapitel är av särskild betydelse ur geologisk synpunkt. Förutsättningen för det nya utvecklingsförloppet var, att det smältvatten som tidigare rann mot väster ned till Glaamdalen, avlänkades mot öster, alltså till Svartisvatnet. Det-



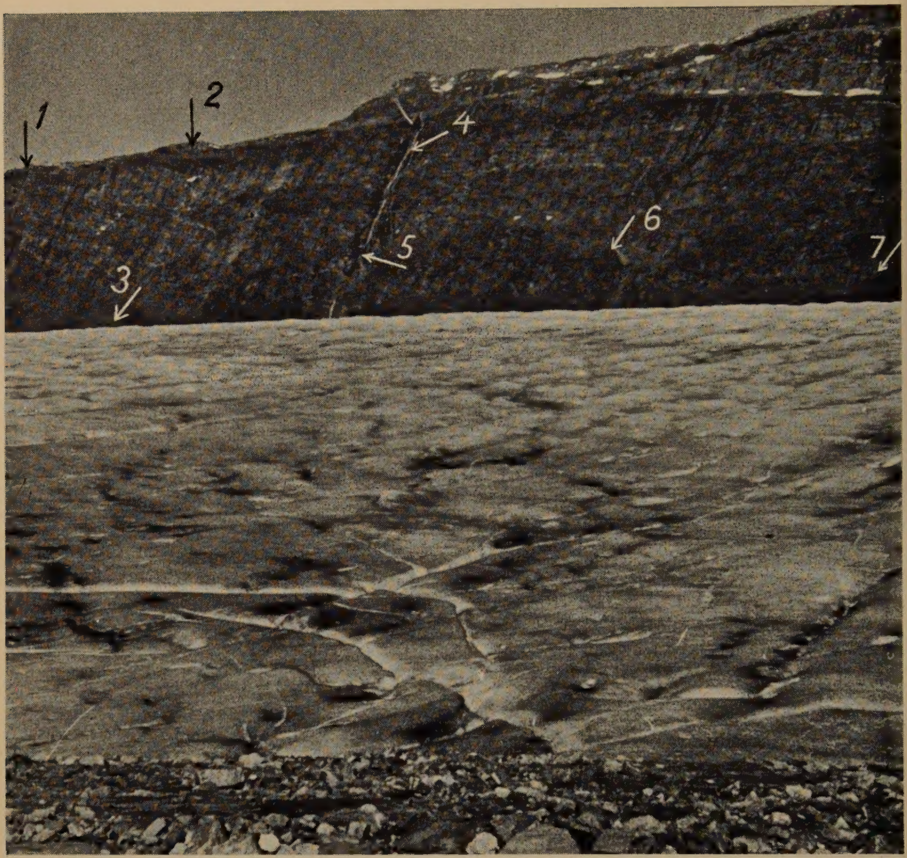
Disa Lundqvist 23. 8. 1960.

Fig. 3. Östra delen av Österdalsisen 1960 från ungefär samma plats som föregående.
The eastern part of the Österdalsisen in 1960 from about the same locality as the picture, Fig. 2. The numbers denote the same points.

ta upptäcktes redan i augusti 1943 av Anton Svartisdal som en morgon fann, att vattnet i älven nedanför gården stigit väsentligt och var ovanligt grumligt. Han insåg, att något måste ha hänt glaciären och begav sig dit. Därvid befanns avloppsälven ha stigit betydligt, varför Svartisdal gick bort till Österdalsisens västra sida vid och öster om kartans p. 285. Där fanns då en isdämd sjö, en Bresjö, vilken — om jag ej missförstod redogörelsen för sammanhanget — då börjat sjunka.

Det måste sålunda vara denna Bresjö som dränerades under isen mot öster. Svartisdal misstänkte, att en tömning av bassängen skulle förorsaka översvämning av dalstråket ner mot Mo i Rana och slog larm.

Detta var den skildring jag fick av Anton Svartisdal. Men vid hemkomsten fann jag Holmsens (1949) beskrivning av förloppet. Därav framgår, att processen började redan 1941. Maximet var 50 m^3/sek mot normalt 3,4 m^3. Sam-

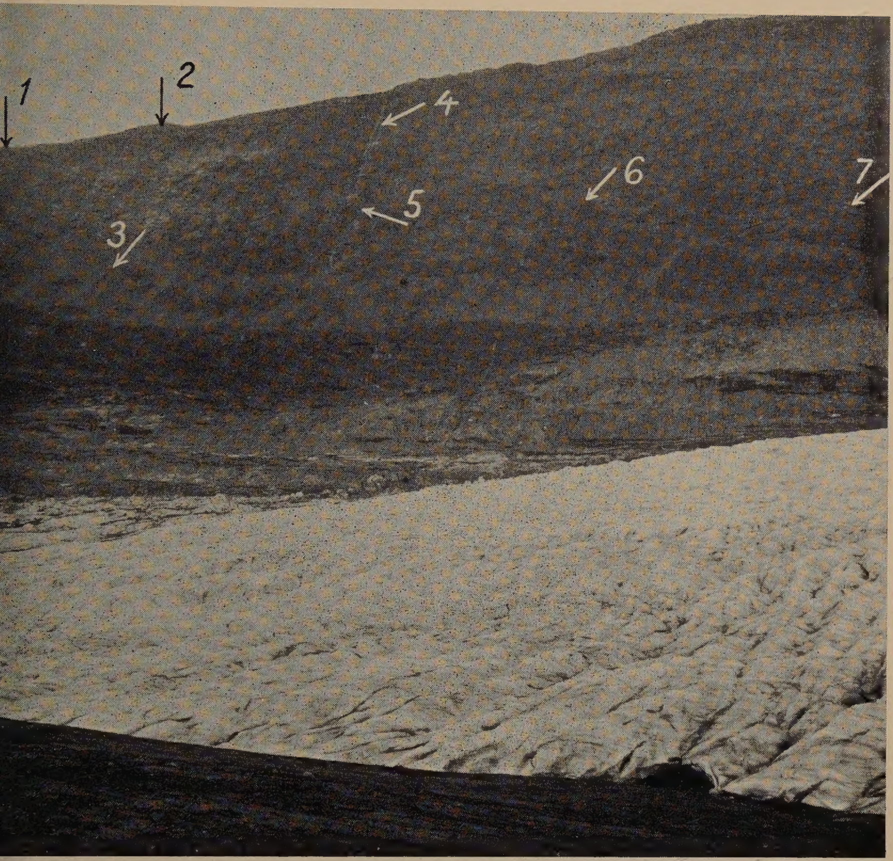


G. Lundqvist 22. 8. 1935.

Fig. 4. Västra delen av Österdalsisen 1935. Ytan är mjukt välvd och föga sprucken.
The western part of the Österdalsisen in 1935. The surface is gently formed and with few crevasses.

ma år, 21—22 september, alltså kort efter flodens maximum 5 september, besöktes området av de båda ingenjörerna Holst och Storsveen från »Vassdragsvesenet». De konstaterade då, att den lilla sjön betecknad p. 285 på kartan var torrlagd och bottnen låg 25 m lägre än dess passpunkt på fast berg. Där låg fullt med väldiga isblock och även isen öster därom var starkt söndersprucken och omöjlig att beträda. Vattnet var avlänkat mot Svartisvatnet.

Följande år (1942) konstaterade ingenjör Langeland, att Bresjön fyllts, och vattnet rann återigen mot väster. Vattenmängden mot väster var 35 m^3/sek. och mot Svartisvatnet 15 m^3/sek. Här möter en anmärkningsvärd uppgift: varje sommar utom 1943 och 1945 — sistnämnda år senare än vanligt och därför förbisett — bröt sig högvattnet ut till Svartisvatnet. Enligt Svartisdals uppgift var det just 1943, som han först skulle ha iakttagit händelseutvecklingens början. Vattenståndstabellen vederlägger emellertid den uppgiften, men i övrigt bestyrkes hans skildring.



S. af Ekenstam 23. 8. 1960.

g. 5. Västra delen av Österdalsisen 1960 från ungefär samma punkt som föregående. Isen är starkt sönderspruckna. Närmast isen till vänster synes Bredsjön (jfr fig. 7.)

ie western part of the Österdalsisen in 1960 from about the same locality as the picture, Fig. 4. The ice s very rich in crevasses. At the ice to the left the ice-dammed lake (Bresjön) is seen; compare Fig. 7.

Av stort intresse är, att glaciärens västra tunga var flytande i Bresjön. Där-
enom skapades förutsättningen för ett ur geologisk synpunkt intressant ut-
:cklingsförlopp. Den fasta isens gräns mot den flytande var enligt af Eken-
am och Holmsen (1949) en tydlig isbräcka. Ännu 1960 kunde vi se en distinkt
ıgefär N—S-lig spricka i den fasta isen. Det föreföll att vara anläggning till
ı ny bräcka.

Det intressantaste är, att bassängen fylldes av isblock som blev kvarliggande
nge i densamma och alltjämt fyller upp en stor del av dess område (fig. 7).
ellan blocken står lergrumligt vatten. Hela området företer en sådan bild av
smältande is, vilken man förknippar med en typ av ablationsmoränens bild-
ngsmiljöer. Skillnaden är, så vitt jag kunnat se, endast den, att Österdalsisen
så ovanligt fattig på moränmaterial. Normalt torde en glaciär eller landis i
tta stadium hysa rikligt moränmaterial. Svartisen däremot är, där man kan

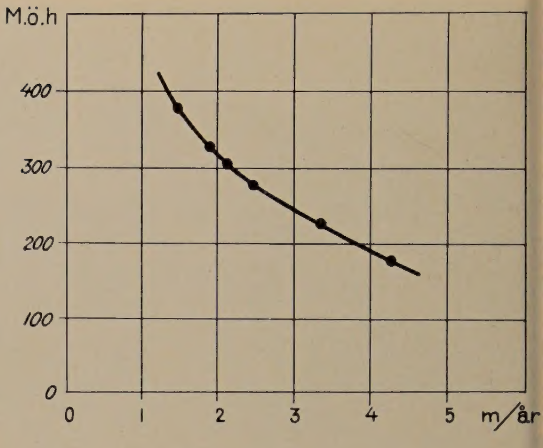


Fig. 6. Avsmältningskurva för Österdalsisen enligt observationer 1935 (se Granlund och Lundqvist 1936). Avsmältningen är koncentrerad till en kort tid på året, men den är här beräknad på totalförloppet 1897—1935.

The ablation curve of the Österdalsisen according to observations from 1935 (compare Granlund and Lundqvist 1936). The ablation is concentrated to a short part of the year, but it is here determined for the whole period 1897—1935.

gå in under densamma, nästan fullständigt ren blåis ända ned till det fasta, blankskurade berget. Sålunda kunde jag på ett ställe mäta fina räfflor från N 70° O ca 50 m in under isen.

De väldiga, upp till 10 m höga isblocken i bassängområdet medför att avdunstningsytan ökar högst väsentligt, och därmed ökar också avsmältningen. Man kan därför förmoda, att området hastigt blir isfritt.

Det är ju detta smältvatten som utgör riskmomentet för Mo i Rana. Det gällde därför, att hastigt men ändå utan katastrofrisk få bort smältvattnet. Därför sprängdes en tunnel i fasta berget under isen till branten nedanför iskanten i öster. Om denna tunnel och dess mått har överingenjör P. T. Smith, f. n. vid Røssåga Kraftanlegg, välvilligt lämnat mig följande uppgifter. Tunneln är 2,5 km lång och tvärsektionen 15 m^2 (3 × 5 m). På en kortare sträcka måste den på grund av bergets beskaffenhet — sprickig glimmerskiffer — delas upp i två sektioner på vardera 7,5 m^2. Detsamma är fallet vid östra mynningen ca 400 m NV om nordvästra viken på topografiska kartan. Intaget ligger sålunda 3 km VNV om samma vik. Förberedelserna drog ut på tiden till hösten 1955 och genomslaget ägde rum 9.5.1959. Nu är det en dånande vattenmassa som sprutar ut ur tunneln, medan avrinningen genom det naturliga utloppet högre upp i branten är relativt obetydlig.

Utvecklingen av glaciären eller rättare sagt dess avsmältning torde helt bestämmas av förloppet i väster. Isen torde komma att brytas upp successivt mot öster, så att hela den forna Österdalsisen försvinner. Norr därom blir ett isfall nedanför huvudisen. Marstrander (1911) anser dock, att den östra grenen kommer att försvinna först.

Strax söder om detta område syntes i regndimman en ungefär O—V-lig sänka, som möjligen utgör en stor spricka. I vilket fall som helst gav denna intryck av att innebära en svaghetszon i isen, längs vilken avsmältningen sannolikt påskyndas. Om så blir fallet kommer sannolikt Österdalsisen att avskäras från isfallet genom ett isfritt område. Utformningens detaljer beror naturligtvis på den underliggande bergytans morfologi.

S. af Ekenstam 7. 8. 1957.

ig. 7. Bresjön framför västra iskanten 1957. Obs mannen framför isen ca 1 cm från högra bildkanten och mannen på isen ca $1^1/_2$ cm från nedre kantens mitt.

ake Bresjön (the ice-dammed lake) in front of the western ice border in 1957. Notice the man in front of e ice about 1 cm from the right margin of the picture and the man on the ice about $1^1/_2$ cm from the middle of the lower margin.

Isens avlagringar

Som redan antytts är Österdalsisen ytterst fattig på moränmaterial eller and-
minerogena beståndsdelar. Det som man väl närmast skulle kalla morän är
us utan finmaterial; närmast liknar det isälvsgrus i mycket tunna lager. Ofta
dess mäktighet < 1/2 m. Allra vanligast är dock, att hällytan framför isen
gger blottad eller beströdd med enstaka småstenar. Det förefaller därför onö-
igt orda om den saken, men ett par detaljer är dock av intresse.

Mitt för sydvästra delen av istungan fanns några grusryggar sträckta i ca
10° O. Höjden var högst 1/2 m, bredden ett par meter och längden mindre
50 m. Intill dessa ryggar syntes fina räfflor från N 60° O. Det är alltså 50°
nkel mellan ryggarna och isrörelseriktningen, och därför är det osannolikt,

att något orsakssammanhang dem emellan råder. Ryggarna är tämligen gracila företeelser, varför det är troligare, att de är yngre än räfflorna. Ryggarna skulle sålunda möjligen registrera den allra sista isrörelseriktningen, då icke ens räfflor utbildades.

På några ställen längs iskanten och på olika avstånd därifrån, ≦ 100 m, iakttogs små högar av ren sand. Det torde väl vara Holmsens »spredte grushauge for bruepanden, bestående af fint sand, tildels synkesand». Höjden är högst någon meter, längden i iskantens riktning högst 10 m och bredden 1—2 m. Ett gemensamt drag hos högarna är, att de visar en skarp iskontakt. Med tanke på isens obetydliga innehåll av sand—grusmaterial är bildningen av dessa små sandhögar gåtfull. Om man funne likartade i t. ex. en svensk skog, skulle man säkerligen skylla på en kortvarig isdämning. Mitt intryck var dock, att en isdämning knappast kunde ha kommit till stånd på det välvda fjället framför Österdalsisen. Troligtvis har det i isen funnits en lokal ansamling av sand som längs en spricka spolats ut till iskanten.

Båda de avlagringar som här omnämnts torde vara helt efemära. Främst beror detta på den ringa mäktigheten och det hala underlaget, glimmerskiffer. Av stor betydelse är säkerligen också den höga nederbörden, som lätt torde spola berget rent.

Västra istungan, som jag ej tillräckligt känner har enligt Holmsen rikligare avlagringar.

Återblick

Avsikten med denna lilla uppsats är att fästa uppmärksamheten dels på den starka avsmältning som ägt rum under de 25 åren mellan mina besök, dels på studiemöjligheten i väster. För kvartärgeologer är det säkerligen av intresse att följa utvecklingen av området framför västra tungan. Den kanske kan ge synpunkter på åtminstone vissa sidor av ablationsmoränens bildning. Själva det med väldiga isblock beströdda området är möjligen riskabelt att beträda på grund av lös botten i småpölarna, varför jag tillråder all försiktighet där.

Men så snart isblocken smält bort — detta är fallet inom västra delen av det ursprungliga Bresjöområdet — bör en noggrann kartläggning, såväl morfologisk som geologisk, av området företagas.

Till intendenten Sture af Ekenstam, som på olika sätt varit mig behjälplig såvä på Svartisen som efteråt genom att skaffa mig bilder och kontrolluppgifter uttalar jag min tacksamhet. Jag är likaledes tack skyldig överingenjör P. T. Smith vid Røssåga Kraftanlegg (Korgen, Norge) för kartmaterial och välvilliga upplysningar.

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Johan Gunnar Andersson

En levnadsteckning

Av

Erik Åhman

en generation av svenska naturvetenskapsmän, som var verksam omkring lskiftet, utmärkte sig ej blott för forskarinsatser i hemlandet utan även i skilda fjärran länder och i polarregionerna. Flertalet av dessa ha gått ur n för flera decennier sedan, och en bland de sista, som också var verksam sin ålders höst var professor Johan Gunnar Andersson.

an var född i Knista i Örebro län den 3 juli 1874 och avled i Stockholm 29 oktober 1960. Efter studier vid Uppsala universitet avlade han fil. lic. nen 1901, förordnades till docent i geologi samma år, blev fil. dr 1902 och ehöll geografiprofessuren där 1906. Redan vid unga år ägnade han sig åt traktens geologi och insamlade fossil, vilka han överlämnade till Natur- riska Riksmuseet. I sina memoarer berättar Andersson, att han som er- la för detta en gång erhöll 50 kronor, vilka han emellertid returnerade hänvisning till att han arbetade för vetenskapen och därför ej kunde taga t betalning! De längre fram systematiskt utförda undersökningarna av brosiluren i Närke och på Öland resulterade i uppsatser om Paradoxides- ns utbredning i Närke, om fosforiterna och deras bildningsbetingelser och de öländska raukarna. Sommaren 1894 tillbringade han tvenne veckor till- nans med dåvarande docenten Rutger Sernander på Gotska Sandön för ier av sanddynernas rörelser och det istransporterade blockmaterialet. Un- ökningarna av de sistnämnda resulterade i en uppsats om de baltiska erup- s ålder, i vilken poängteras rapakivibergarternas prekambriska ålder.

m ung student deltog han i expeditioner till de arktiska regionerna. Så- a var han medlem av polarforskaren A. G. Nathorsts expedition till Spets- en, Kung Karls land och Vitön 1898. Året därpå företog han en egen ex- tion till Björnön, och de geologiska resultaten från denna färd framlade i gradualavhandlingen »Über die Stratigraphie und Tektonik der Bären ». När Otto Nordenskjöld företog den ryktbara sydpolsexpeditionen med arctic» åren 1901—03 blev Andersson hans närmaste man. Sedan Nor- kjöld med några av expeditionsdeltagarna gått i vinterkvarter på Snow Hill og Andersson ledningen av expeditionen till Sydgeorgien, Falklandsöarna Eldslandet samt under fartygets andra färd till Antarktis. Andersson läm- därefter fartyget med tvenne följeslagare för att över land ta sig fram Nordenskjölds vinterkvarter i Snow Hill. Innan han nådde dit blev han tat tvungen till en övervintring i Hoppets vik under synnerligen primitiva prövande förhållanden i en i all hast uppförd hydda. Följande vår sam-

manträffade han med Nordenskjöldsgruppen. Under tiden förliste »Antarcti
i packisen. Denna expedition och dess räddning genom en utsänd argentin
undsättningsexpedition hör till de mera spännande kapitlen i polarforskninge
historia. Bland övervintrarna i Nordenskjöldsgruppen på Snow Hill befann s
en argentinsk marinofficer och geolog, José María Sobral, som sedermera ko
till Sverige, studerade geologi i Uppsala och småningom framlade en gradu
avhandling över berggrunden inom Nordingråområdet, Ångermanland. I
annan av övervintrarna var den endast en månad efter J. G. Andersson bo
gångne professor emeritus G. Bodman, som åren 1916—40 var professor
kemi, mineralogi och geologi vid Chalmers tekniska högskola. — Även svens
staten utrustade en undsättningsexpedition, som anlände till Snow Hill o
Hoppets vik ungefär tre veckor senare än den argentinska. En fransk undsä
ningsexpedition kom till Buenos Aires lagom för att deltaga i hyllningarna f
Nordenskjölds expedition och dess räddare. De vetenskapliga resultaten fr
sydpolsexpeditionen framlade Andersson i ett flertal skrifter berörande bl.
de geologiska förhållandena på Grahams land och stenströmmarna och jo
flytningen (solifluctionen) på Falklandsöarna.

År 1906 förordnades Andersson till chef för Sveriges geologiska unders
ning, vilken befattning han frånträdde med nådigt avsked 1916 efter att
åtnjutit tjänstledighet sedan 1914. Under sin jämförelsevis korta chefstid l
kades han med att på Undersökningens arbetsprogram upptaga till behandli
en mängd nya och viktiga uppgifter. Sålunda inriktade han Undersökning
verksamhet på uppgifter av aktuell praktisk betydelse samtidigt som den vet
skapliga forskningen främjades. Det gällde bl. a. utvinningen av olja och an
tekniska produkter liksom radium ur de bituminösa skiffrarna. Den år 1
stadfästa organisationsplanen för Geologiska undersökningen, som haft gilt
het ända fram till våra dagar, var till stora delar hans verk. Under Anderss
chefstid uppfördes för Geologiska undersökningen nya rymliga lokaler i en m
Naturhistoriska Riksmuseet gemensam byggnad vid Freskati. Under hans ve
samhetstid började SGU:s årsbok att utgivas.

Under den XI Internationella geologkongressen i Stockholm 1910 var A
dersson dess generalsekreterare. Här fick han ta itu med ett vidlyftigt organi
tionsarbete, vilket fullföljdes på ett sätt, som i hög grad bidrog till att g
svensk geologisk forskning känd i utlandet. I samarbete med H. Munthe o
A. Gavelin redigerade han kongressens publikationer, bland vilka märkes d
en omfångsrik uppgiftsammanställning rörande världens järnmalmstillgång
dels ett större arbete om de senkvartära klimatförändringarna. Flertalet av
kursionsguiderna trycktes i Geologiska Föreningens Förhandlingar.

Som ovan antytts hade Andersson redan 1914 erhållit tjänstledighet från
befattning som chef för Sveriges geologiska undersökning och gått i den ki
siska regeringens tjänst som rådgivare och organisatör av en geologisk und
sökning av Kinas malm- och mineraltillgångar. Under denna tid vann han
stora berömmelse som Kinaforskare. Förutom de malmgeologiska arbet
medhanns även omfattande undersökningar av Kinas djur- och växtpaleon
logi. Ingående studerades de kinesiska tertiära och kvartära avlagringarna,

JOHAN GUNNAR ANDERSSON

därvid klarlades förhållandena mellan löss-sedimentationen och andra bil
ningar, som dittills förväxlats med dessa. I samband härmed åstadkom ha
stora samlingar av fossil, som belysa förhållandena inom en tidigare ofullstä
digt känd och utdöd djurvärld. Anderssons arbeten ledde till förutsägelser o
att man i trakten av Peking borde ha stora möjligheter att påträffa rester
homider, »urmänniskor». Den från professor Carl Wiman i Uppsala utsän
forskaren professor Otto Zdansky företog nu utgrävningar av benbreccior i
däggdjursfossilrik grotta därstädes. I det till Uppsala hemförda materialet p
träffade Zdansky omkring mitten av 1920-talet vid prepareringen två homini
tänder. På senare år har denne påträffat ytterligare en tand i materialet. V
fortsatta arbeten i den stora fyndgrottan påträffade uppsalapaleontologen Bi
ger Bohlin bl. a. en tand och skallbensfragment. Någon tid därefter påträffa
tvenne kinesiska forskare ytterligare tänder och större skalldelar av hominide

Under senare år organiserade Andersson arkeologiska utgrävningar, som ka
tade ljus över Kinas tidigaste bebyggelse. I sina arbeten fick han kraftigt st
från såväl den kinesiska regeringen som den svenska riksdagen och enskil
mecenater. Riksdagen anslog sålunda år 1919 90 000 kr. till utgrävningar o
undersökningar i Kina. Från sitt arbetsfält hemförde »Kina-Gunnar», som ha
benämndes i vida kretsar, omfattande samlingar, vilka nu förvaras i skilda m
seer i Sverige. För beskrivning av forskningsresultaten startades vid Geologic
Survey of China en i 4 serier utgiven »Palæontologia Sinica».

År 1924 kallades Andersson till den efter Gerard De Geer lediga professur
i geologi vid Stockholms Högskola, vilken befattning han dock lämnade red
1926. Han utnämndes därefter till föreståndare för de Östasiatiska samlingar
i Stockholm och erhöll en personlig professur i östasiatisk arkeologi, vilken ha
sedan innehade till år 1939.

Resultaten av sitt forskningsarbete framlade Andersson i ett omfattande v
tenskapligt författarskap. De sammanfattande resultaten från åren i Antark
har han bland andra förf. framlagt i »Antarctic, två år bland Sydpolens isa
(1904), och forskningarna i Östasien i »Topografisk-arkeologiska studier i Fjä
ran Östern» (1939). Andersson hade stor förmåga att popularisera sin vete
skap, dels som föredragshållare, dels som författare. År 1926 utgav han kin
skildringen »Draken och de främmande djävlarna» följd av »Den gula jorde
barn» (1932), den självbiografiska »Kineser och pingviner» (1933) samt »U
der brinnande krig» (1938).[1] Sitt liv och sin livsåskådning har han även skil
rat i ett arbete »Mitt liv och min tro» (1956).

Under sina år som chef för Sveriges geologiska undersökning tog han livli
del i Geologiska Föreningens arbete. Han var sålunda ordförande år 1908 o
ledamot av styrelsen åren 1909—1912.

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[1] Den sistnämnda handlar om Anderssons sista expedition till Kina åren 1936—38.

Tectonic Fabric of a Sequence of Areas in the Scandinavian Caledonides

By

MAURITZ LINDSTRÖM

ABSTRACT

Fabric data (chiefly *s*-surfaces and lineations) have been collected in twelve areas
ong a 200 km long NE—SW line in the northern Caledonides of Scandinavia. The
drock consists of overthrust laminated rocks tending to be sub-horizontal S-tectoni-
s. In 241 instances, lineations striking about NW—WNW have been deformed by
all folds of other strikes. This is part of the evidence for postulating different
ases of deformation. The main lineation maximum for the areas strikes WNW.
neations with this strike are strongly correlated with local β-maxima with the same
ike. However, the main β maximum for the areas strikes NW. Movement directions
e discussed, *i.a.* on the evidence of 720 instances of small overturned folds. Bou-
nage shows a preferred orientation that is not obviously correlated with either the
ongest lineation maximum or the strongest maximum for β. Joints are as a rule
t obviously correlated with other fabric elements and appear to have been formed
ter folding had ceased almost entirely.
ethodology: A 0.25 % counter has been used for the diagrams. A method is
scribed whereby an infinite number of projection poles may be counted out.
rikes are referred to a great-circle that has been constructed to correct for the
nvergence of the meridians near the geographic pole.

Introduction

The eastern strip of the Scandinavian Caledonides consists of overthrust
minated rocks that are almost parallel and horizontal over vast areas. In this
vironment there has obviously been little external rotation, compared with
her strongly tectonized regions, and structures have therefore largely preserved
eir original trends. This offers exceptionally favourable conditions for a
storical approach to the structures.

A few years ago, I made rather detailed structural work in a small area
km^2) in the northern Caledonides of Sweden. When all the fold strikes were
ranged on a map of the area (local synthesis, Lindström 1960) the result ap-
ared to be an incomprehensible mess. However, when all of the fold axes
re projected together in a stereographic diagram (functional synthesis, Lind-
öm 1960) I found that they belonged to a few distinct populations with
erence to orientation. Members of these populations occurred mixed together
over the area. This was interpreted as an indication of distinct phases of
formation with different directions of material transport, each phase having
ected, more or less, the whole area (see Lindström 1955).

Next, I assumed the working hypothesis that there might be traces of the same deformations in near-by areas as well, possibly with some deflections of axial trends. If the areas chosen for comparison were not too distant, the possible deflections of trend might be relatively small, and the orientation groups of fold axes might not be too different to be comparable between the areas (Lindström 1956).

As the work progressed from area to area, southward along the Caledonian strike, it appeared that the axial trends were not only comparable, but almost identical from area to area (Lindström 1957, 1958 *a*, 1958 *b*). It became plausible that the investigated lengthwise section (85 km long) of the mountain chain had been affected by several phases of deformation, each phase with its own strike trend that did not change much (or at all) from area to area. Several methods were used for determining the age-relations between the phases.

In the present paper the investigated section along the Scandinavian Caledonides is extended southward so that it is now 200 km long and comprises 12 small areas. All tectonic data, including the ones already dealt with in previous papers, are worked through with more exact methods. The results presented here are based on the new data together with the revised old data, and are independent of earlier results, which they largely replace.

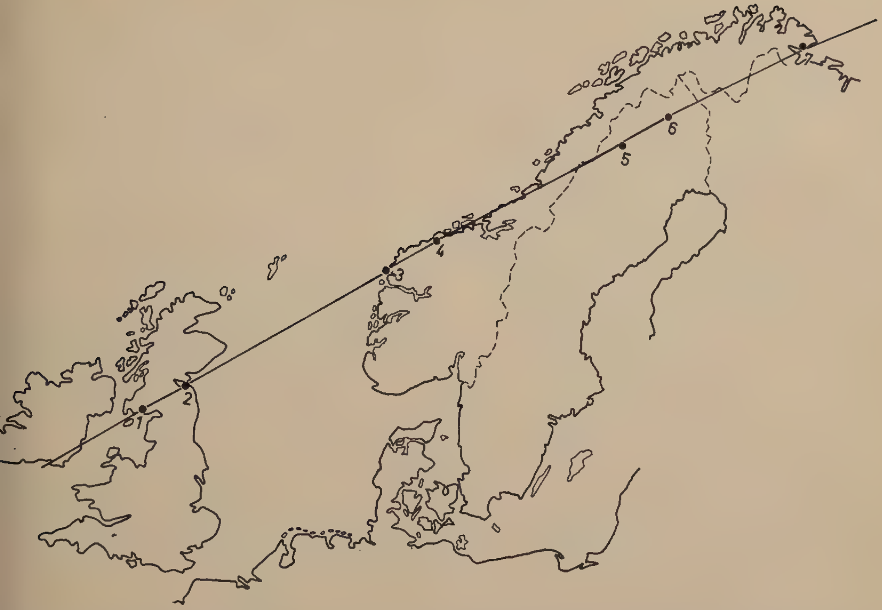
Two lines will be followed in this paper. The first, and main line will be to summarize all the data of each given kind for all the areas. The great number of the data involved in these synopses will perhaps make preferred orientations and other trends appear with some certainty. This approach is permissible only if one keeps in mind that its results are not necessarily true for any other sample than the one from which they are obtained. Component, smaller samples, for instance the isolated data from any of the twelve small areas, might yield different results.

The other line, which is subordinate here, will be to try and trace fabric regimes from one area to another and see if there are any tendencies toward deflections. The quantitative basis for this approach is necessarily weaker than for the first. I intend to deal with the areas one by one in a forthcoming paper In that context the second approach will of course predominate over the first

A Reference Line for Structural Comparisons

If we are to make valid comparisons between tectonic axes of different areas we must have a straight-lined rectangular reference net to which we refer the strikes of the axes. This condition can be approximately fulfilled in small areas on the geoid. Only near the equator will the geographic coordinates meet the requirement to a satisfactory degree for larger areas. For areas near the poles other references are necessary.

In the following, I call those lines parallel which make the same angle with a great-circle that cuts both lines. Geometrically, those lines are parallel only in special cases. However, if one unrolls the tangental cylinder of the great



. 1. Caledonian reference line, to correct strikes for convergence of meridians. The at-circle through 54° N., 5° W., and 70° N., 30° E. passes by Kirkcudbright (1) and N. wick (2), through Florø (3) and Molde (4), immediately N of Kvikkjokk (5), through Kiruna (6), and S of Vadsø (7).

cle, the tangental lines that make the same angle with the great-circle will come parallel geometrically.

In order to discuss what tectonic axes that are parallel in two different areas, e should then have a great-circle that passes through both areas. As an aid in comparison of tectonic axes within a mountain chain, one may conveniently oose as a reference line the great-circle that is the most nearly parallel to the untain chain in question. I have chosen as reference line for the Caledonides N.W. Europe the great-circle that passes through Lat. 54° N, Long. 5° W d Lat. 70° N, Long. 30° E. The concerned part of the course of this circle is own on the map, fig. 1. This line will in the following be called Caledonian ference Line (C. R. Line). Strike directions given with reference to this line called C. R. strikes. The C. R. Line is taken as 0°, and strikes referred to are counted clock-wise.

The reference great-circle makes different angles with the meridians along run. This is of course precisely why it is required. Thus, at N 54°, W 5° it kes 31° with the N direction, which may be expressed thus, C. R. 0 = 31° E. At N 70°, E 30°, we find C. R. 0 = N 62° E. This means that a fold iking N near the former point, or, let us say, on the Isle of Man, will make 2—31)° with a fold observed to strike N at the latter point, or about Vadsö northernmost Norway. The C. R. strike of the first fold will be (180—31), 149, that of the second, (180—62), or 118.

In order to know the C. R. strikes in a certain area we must know the angle between the local meridian and the reference line. This angle is given for different meridians in the following table.

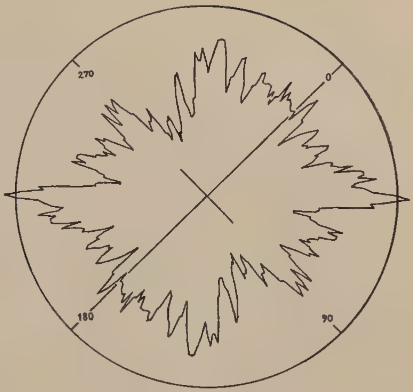
Long.	Angle between meridian and C. R. Line	Long.	Angle between meridian and C. R. Line
W 5°	31 °	E 15°	48. 6°
3°	32. 6°	17°	50. 4°
1°	34. 3°	19°	52. 2°
0°	35. 2°	21°	54. 1°
E 5°	39. 5°	23°	55. 9°
7°	41. 3°	25°	57. 8°
9°	43. 1°	27°	59. 7°
11°	44. 9°	29°	61. 5°
13°	46. 7°	30°	62. 4°

I am indebted to Dr. Thorild Dahlgren, of the Astronomical Observatory of Lund, for indispensable help with the spherical trigonometry in connection with the reference line.

C. R. strikes in an area not too far removed from the reference line are the same as those in an area at the same longitude, on the reference line. Take, for instance, the Oslo area, where many fold structures strike approximately in N 60° E. Now, the Oslo area lies nearly on Long. 11° E. The C. R. strike for these folds will then, by the use of the above table, be found to be (60—45), or 15, as C. R. 0 = N 45° E.

The polar convergence of the meridians was not considered on constructing the synoptic diagrams for the Scandinavian Caledonides in Lindström 1959. The effect of this convergence can now be eliminated with the help of the C. R. Line. It seems worth-while, then, to rework the material used for my synoptic diagrams, bringing in the correct C. R. strike for each datum. The result, fig. 2, is surprisingly little different from its counterpart, D3 in Lindström 1959 that is founded on the same data, referred to the geographic North. A further discussion of the diagram will follow later on, together with comparison with other diagrams. For the present, it only needs to be added that the diagram shows the strike frequency in five degrees about any given degree. The frequency recorded for instance at 90 thus includes strike data ranging from 88 to 92, inclusive.

After I had constructed the C. R. Line, I found that Élie de Beaumont had had a very similar notion; with a largely identical reasoning behind it (1847 pp. 6—7). However, in constructing his *grand cercle de comparaison,* Élie de Beaumont departs from a set of strikes that are already known, and calculates the great-circle with which they all tend to be parallel, whereas my C. R. Line is independent of local strikes and should serve as a reference for any orientations of axes that may be found along its limited course.



g. 2. Frequencies in 5° for Caledonian reference strikes of linear fabric elements in Scanavian Caledonides. Same data, and same tistical treatment of data, as in D3, Lindöm 1959. 0—180 = strike of reference line. Circle = frequency 100.

The convergence of the meridians in the strip dealt with in this paper is out 2°, which makes the C. R. Line necessary for accurate structural comrisons.

Geography and Geology of the Areas

The data presented in this paper were collected in twelve areas, ranging in ze from 9 km² to about 90 km². The areas are situated with rather regular tervals, roughly on a line that is 200 kilometers long and runs along the mean ctonic strike, *i.e.*, in N.E.—S.W., from the north-western end of the lake orneträsk in Sweden (Long. 18°36′ E, Lat. 68°28′ N) to the northern shore the lake Balvatnet in Norway (Long. 15°56′ E, Lat. 66°59′ N). The areas e called, from north to south, (1) the Pålnoviken area, (2) the Nuolja area,) the Kartimvare area, (4) the Allesjaure area, (5) the Haukajaure area,) the Sitasluspen area, (7) the Vaisaluokta area, (8) the Vastenluspen area,) the Jaurekaska area, (10) the Staddajokk area, (11) the Lommi area, and 2) the Balvatnet area.

In each area about 45 localities were sampled. In the northernmost area, here the exposures were good and the structures complex, sampling was much ore detailed. All localities are at such topographic features as are easy to calize on the maps or in the terrain, mainly stream-courses, as these provide e best (and, in some cases, the only) exposures.

The bedrock of all the areas under discussion forms part of a vast sheet of etamorphic rocks that rest on the whole almost horizontally on a basement Archean crystalline rocks and post-Archean sediments, largely shales and ndstones. Whereever one can observe the contact between the metamorphic cks and the basement, one finds that it is a tectonic discontinuity.

The deepest part of the overthrust complex in my areas consists of strongly eated gneisses, micro-grained and finely laminated in the north (hard-schists areas 1—6), mostly with a slightly coarser texture in the south (areas 6, 7). e gneisses in the south develop into hard-schists just beneath the (tectonic) undary toward the next higher units.

Above the gneissic rocks there follow mica-schists, mostly with biotite, with or without macroscopic garnets, and in some areas with hornblende-sheaves. In the mica-schists are intercalated carbonatic zones. In area 3 there is a thick amphibolite sheet above the hard-schists. In areas 7—12, more or less basic sheets (green-schists and gabbros) occur within or above the higher mica-schists. Peridotites occurring in areas 8—10 are of no significance in the present context.

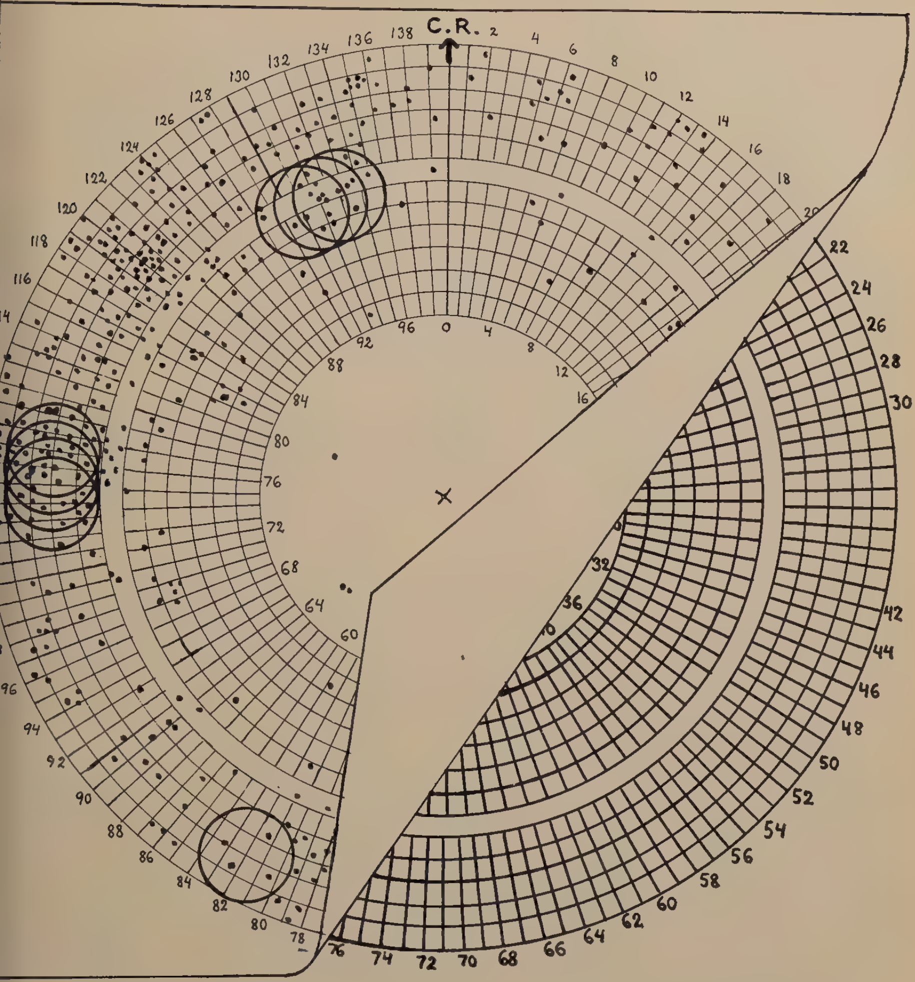
As a rule, one will not find a trace of original structures, but in areas 8—12 there are localities with recognizable sediments (largely greywacke conglomerate) and volcanics (see Vogt 1927 and Kautsky 1953). There are even in areas 8 and 11 some limestones with fossils that can be identified as to their general systematic positions. These fossils do not allow a safe determination of stratigraphic age, but it seems at least certain that the fossiliferous rocks are not older than Ordovician (*cf.* Vogt 1927, p. 481, Kautsky 1953, p. 52).

Most of the schists are very nearly S-tectonites in the sense of Sander (1948, p. 70). As already mentioned, the thrust is about horizontal over a very great distance. Compared with the vast horizontal extent, the thickness of the remains of the overthrust sheet is very small, probably about 1 500 meters, at the most, but generally much less. This preserved basal zone of the overthrust masses is dominated as regards fabric by the nearness to the downward limit of the thrust movement. Perforce, the material has flowed more or less parallel to the underlying, nearly horizontal thrust. Within the overthrust complex, there also occur separate distinct planes or zones of particularly strong differential movement. These zones are also sub-horizontal, and frequently separate lithologic units (tectonic-stratigraphic units) from one another. The most important of these movement zones or planes is the one that separates the basal gneissic schists from the overlying, so-called "Seve" mica-schists. The deformation is thus closed in between sub-horizontal zones of particularly strong shear. These conditions are important to remember, if one compares my methods and results with what is considered to apply in the more freely folded strips of the Caledonides, for instance the Central Highlands of Scotland.

The Use of β

β are the constructed intersection-lines of *s*-surfaces (by which in this paper is meant schistosity and foliation in the sense of Harker 1952). β intersections are constructed because it is believed that they generally tend to coincide with fold-axes, although it is improbable that any given single β intersection actually does have this significance.

The *s*-surface orientations noted at each locality were used for constructing a diagram for that locality. As β axes are more likely to represent true fold axes, the closer together the *s*-surfaces occur, the extent of the locality and thereby also the number of *s*-surfaces must be rather restricted. The localities were so delimited that they contained as a rule 13 or 14 *s*-surfaces with perceptibly different orientations within as small an area as possible. The widest



ig. 3. Instance of fixed grid over which diagrams are counted out, for eventual summa-on. The grid is constructed for areas with sub-horizontal axes. A tracing-paper with projection points covers most of the grid. Circlets represent different positions of a 1 % counter cell.

calities cover distances of about 200 meters, but most localities are many times naller. As the chief interest with the *s*-surfaces concerned their intersections, , one is little helped with parallel surfaces. Thus, the only selection imposed n the material is that all the *s*-surfaces of a certain locality must diverge more less, perhaps only by a couple of degrees of dip. Even a very small such vergence is observable without instruments.

The analysis of the recorded data begins with the construction of a stereo-aphic diagram for each locality, and is carried out after the field work is mpleted. A Schmidt net is used. The locality diagram contains the normals the *s*-surfaces, the *β* intersections that can be constructed for the recorded *s*-surfaces, and the lineations found at the locality. The number of β depends on the number of *s*-surfaces. If there are n *s*-surfaces, one gets $n\ (n-1)/2$ intersections. One method to construct the intersections is described in Lindström 1958 *a*. This method uses the *s*-poles (projected *s*-normals). The normal to the great circle through two *s*-poles is the intersection (β) of the two corresponding *s*-surfaces.

Unavoidable errors in β orientation result from the quality of the field data. To get a correct β, two *s*-surface orientations must be correctly determined. However, probably very few experienced geologists would claim that they make dip readings that are always exact to the degree. In particular, it is very hard to get the correct strike of a nearly horizontal surface. Some of the best structural studies that I know seem to be founded on orientation readings to the nearest five or ten degrees. In those cases, it has not been attempted to construct any β. With as high a standard error for the field data as ± 2.5° or 5°, one could not get any useful β. However, by comparing readings on the same rock surfaces done by several students, it has been found that after some training the average error may possibly be reduced to ± 1/2°, or but little more. The error of the observations must be smaller than half the divergence of the *s*-surfaces, if β shall mean anything. If the true divergence of the *s*-surfaces is three times the maximum error of their determinations, the maximum error of β will be about 50°. If the divergence is four times the determination error, the greatest β error amounts to about 30°. If the divergence of *s*-surfaces is eight times the maximum determination error, β may be wrongly displaced by at the most about 14°.

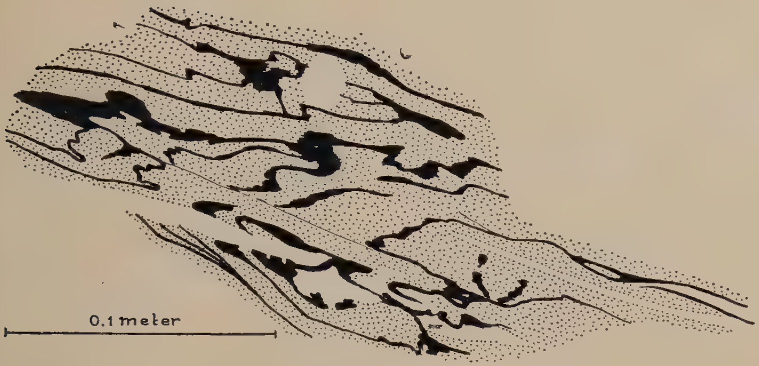
Considering the great errors that may arise in β construction, particularly in tectonites with only slightly diverging *s*-surfaces, it is important to remember that these errors can hardly be anything but random. The significance of evident trends in β orientation is therefore not affected by the errors discussed. Practice has shown that with some effort at precision during the collection of data, one can, even in almost imperceptibly folded schists, get *s*-surface readings that, on being worked through, yield highly significant β trends.

The *s*-surfaces of my areas are nearly parallel, statistically speaking, and almost horizontal. D1 of this paper will show both these features, because the β girdle outlines the mean orientation of the surfaces. D11 in Lindström 1957 shows the orientations of *s*-surface poles in one representative area. In this area the surfaces are sub-parallel and sub-horizontal.

Major overturned fold limbs involving the boundaries of tectonic-stratigraphic units seem not to occur. Faulting of diverse kinds is extremely rare.

All the enumerated circumstances make it possible to employ β (constructed intersections of *s*-surfaces) in the tectonic interpretation. It is maintained that under the conditions sketched above, β will tend to represent fold-axes normal to greatest compressive stresses.

Arguments against this interpretation of β are founded on areas where all orientations of *s*-surfaces and fold-axes occur, and where vertical orientations are not least common (*cf. i.a.* Weiss and McIntyre 1957, and Weiss 1959). The



. 4. Deformation plane of strictly parallel lineations striking in C. R. 59. Looking N71° W R. 239). Locality: Vastenluspen area (8), W side of small stream shown on ordnance map ween Tuojepe and Svartetjåkko. Lower beds of marble formation. Black = graphitic phyllite. opled = grey calcite marble. White = yellowish-white calcite marble. After scale-true field sketch.

eat reorientations of cylindroidal folds that may have taken place in such eas would not occur very commonly in my areas.

Certain features of a cylindroidal fold system which is crossed and disturbed other folds have been discussed by Weiss (1959). The distortions of the β ttern that are rendered conspicuous by strong rotation of *s*-surfaces can be glected in this context, as I have already stated. One such feature described Weiss (p. 98) is that the crossing folds are smooth-limbed and sharp-ested. Here, Weiss indicates that the original cylindroidal folds may not at appear as β intersections. Sharp-crested folds are, however, very rare in my eas. Weiss also shows that β may prove very little, if constructed on the basis a set of fracture-cleavage planes superimposed on a fabric of *s*-surfaces /eiss 1959, p. 104). Fracture-cleavage is, however, extremely rare in my eas, taken together, and has therefore not been used for β constructions.

The following model seems to answer best to the conditions in my areas. ost of the *s*-surfaces of a given locality are assumed to have at first been ated to some, generally slight, extent about axes of one direction (*b*). They re then rotated about axes of direction b', which makes an angle with *b*. e second rotation, like the first, affected the surfaces to rather different ex-ts, but the rotation that did take place was seldom very strong.

After the first rotation, the *s*-surface poles were arranged along a sector of a at-circle girdle, with a tendency toward a normal or possibly a log-normal tribution, the mode of which would contain the poles of the least rotated faces. All β would tend to coincide in direction *b*, normal to the great-circle. After the second rotation that also would have left a mode of little or not ected surface poles, we find that many *s*-surface poles have migrated normal direction b' from the original girdle, but many are still more or less in their mer positions. The original girdle still persists, but is more feeble. There is a ther tendency for *s*-surface poles to fall along a feeble girdle sector through the mode of the original girdle and normal to direction b'. The β concentratio corresponding to this girdle will be parallel to b'.

There will thus be two β concentrations, parallel to b and to b'. These con centrations will be rather feeble. The orientations of other β will be random.

A similar reasoning applies if three or more directions of rotation axes hav occurred within the limits of a locality. The β concentrations will then be sti more feeble.

Certain controls of the tectonic significance of β are afforded by comparison with lineations, and will be discussed further on.

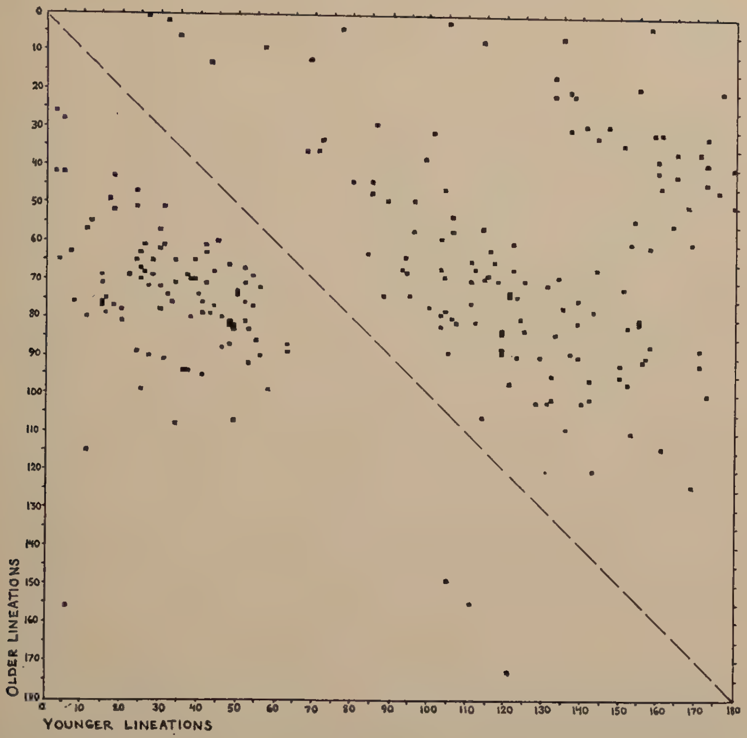
Lineations

The following kinds of lineations may be distinguished. *1. small, distinc folds* with a wave-length of at least about 10 mm, without associated parall structures like striations, etc., and usually with a clear sense of overturning (se text-figures 18 & 19). *2. phyllitic wrinkles* with a wave-length of but a fe millimeters, frequently crowded so as to cover the whole, or patches of a *s*-surface, sometimes a little bit sinuous, and mostly without any tendency to b exclusive. *3. striations,* parallel and quite straight, very densely spaced, an penetrative. There are two kinds, one consisting of minute, often barely visib grooves and ridges (not = slickenside striae, though), and the other being lev with the *s*-surfaces and consisting of an imprinted texture, colour, and miner banding (text-fig. 18 & 19). *4. stretched pebbles, mullions* (see Lindströ 1958 *a*, pl. 3, fig. 2, and present paper text-fig. 17), *rods* (rare), *parallelis of* (dark) *minerals. 5. folds with* (more or less) *irregular deformation plane* completely penetrative, intimately associated with striations of diverse kind as a rule with rigorously parallel axes, often without obvious relations betwee fold-sizes and characteristics of folded beds (see Lindström 1957, pl. 1 and p 2, fig. 1, 1958 *a*, pl. 2, and present paper text-fig. 13).

Lineations that are mere intersections of cleavag planes have not been found.

Intermediates between these categories of lineations are very common. Eve lineation observed in the field in areas 7—12 has been classified. Categori 3—5 are so intimately related that it hardly seems worth-while at present discuss them one by one. The phyllitic wrinkles form a distinct and rath common group, for which a separate synopsis was prepared. In this synops it appeared that the orientations of phyllitic wrinkles do not differ marked from those of other lineations. Greater materials of wrinkles will be necessar before it can be said that they tend to diverge from the rest of the lineatior Perhaps one is thus still entitled to discuss the lineations under one heading the present context.

All the observed orientations of linear elements are connected with *s*-surfac that were recorded for β construction. The orientations of linear elements we not determined directly, but as left-hand or right-hand down-dip angles wi the strikes of the *s*-surfaces. Thus I did not know the orientations direct



ig. 5. C. R. strikes of associated (deformed) older lineations and (deforming) younger ieations (small folds). Points on the broken diagonal line would refer to cases where the associated older and younger lineations were parallel.

hen I recorded them. This elaboration of the observation method in order to void subjectivity may seem unnecessary. However, it is certain that even the ightest subjectivity in the collection of data can have an effect on the patterns big materials.

Method of Counting Out

The projected axes from all the localities of an area are brought together in tal diagrams for the area, chiefly one for all β, one for all lineations, and one r those β which are constructed from s-surfaces that are next to one another my notes (and also in the field). The collective β diagram for an area will ntain about 3 800 projection points, as there are about 45 local diagrams, and —91 β in each local diagram. With such a big number of points in a single agram, special methods of counting out are at once possible and necessary. In e present investigation I have introduced a counter with 1/4 % surface stead of the conventional 1 % counter. The smaller counter means a gain in ecision, but also a loss in reliability. Therefore, it cannot be used advantagesly with smaller materials than about 500 poles in a single diagram unless ere is a very obvious preferred orientation.

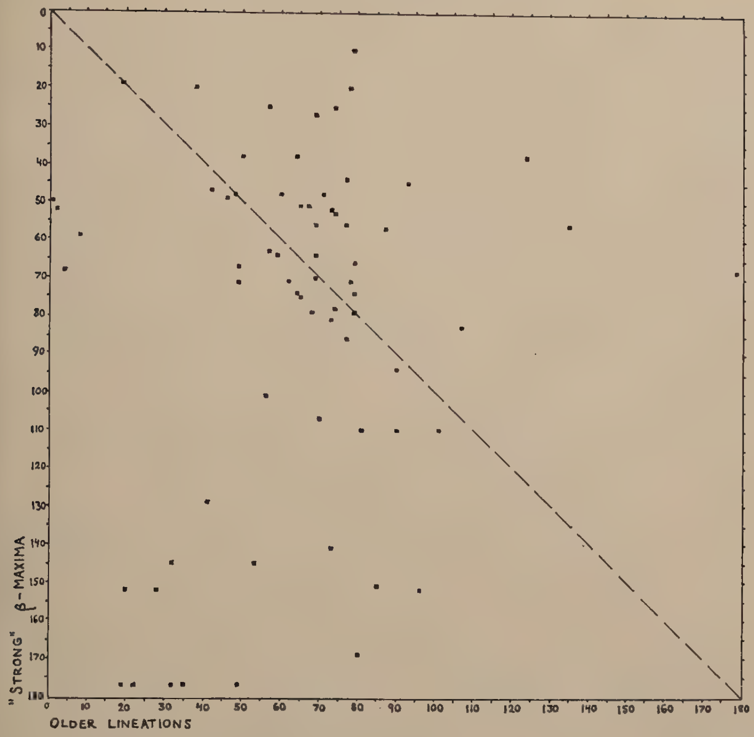
Furthermore, the diagrams are counted out over a special grid. An idea of how this grid is constructed and used should be given by figure 3. The aim of the procedure is that it should be possible to sum up detailed counts on an infinite number of diagrams into a single cover-all diagram. The grid consists of two coordinate systems, one radial and one concentric. The outermost concentric coordinate has the same diameter as the Schmidt net used for the diagrams. The concentric coordinates are given Roman numerals, the outermost being no. I. The radial coordinates are given Arabic numerals, that run clockwise. The grid used in the present investigation is finer than the one figured. There are 254 radial coordinates, and the concentric coordinates are correspondingly closer. For tectonites with sub-horizontal axes, the central parts of the grid can be omitted. A diagram to be counted out is then fitted over the grid, with the Caledonian reference line on a fixed radial coordinate. The counter is moved from one coordinate intersection to the next, and the number of projection points found at each counter position is brought into a table with vertical columns for the concentric, and horizontal for the radial coordinates. After the table has been filled in, it gives a complete picture of the densities for the whole diagram. Isarithms can then be drawn directly on the table, and be transferred from there to a tracing paper that is put over the grid. If one wants to sum up several diagrams counted out over the same grid into a single one, one puts the tables side by side, and adds table items in identical positions, then putting the obtained values in a further table that may subsequently be contoured in the ordinary way, and transferred to a tracing paper.

In the instance given in figure 3, the grid is covered by a tracing paper with projection points. The lower right part of the grid is uncovered. A single 1 % counter circle is placed over the intersection III: 82, and it appears that the number 4 should be put in this place in the table. Four counter positions are shown on coordinate IV. An extract from the corresponding part of the table would look thus.

Coordinate	III	IV	V
104	12	17	13
105	20	*22*	18
106	23	*27*	25
107	29	*31*	29
108	33	*31*	29
109	29	27	31

The numbers of points within the figured counter positions are here italicized. Three other counter positions are shown on coordinate VII (VII: 92—94).

A grid like the one figured has been used in my previous work. As mentioned above, the grid used in the present study is much finer.



6. C. R. strikes of older (deformed) lineations (*cf.* text-fig. 5) and associated local axima in cases where the latter are strong (defined in text). Points on the broken diagonal refer to cases where lineations and β-maxima coincide in strike. Each point refers to the β-maximum and one lineation datum at a particular locality.

β Categories and Lineations, Significance of Compared Distributions

The construction of β intersections and their possible significance has already n dealt with.

The synopses of β are of three kinds. Firstly, all the β intersections from all localities have been brought together (D 1). Area 1 is excluded from this opsis, since the β material from that area is not strictly comparable with t of other areas. If n s-surface data were collected at a locality, this locality yielded $n(n-1)/2$ β intersections to this synopsis. Many, in some cases most, he β intersections of a locality may have random orientations.

n the second kind of β synopsis (D 6) only those β are included that are ained from each two s-surface data that follow next upon one another in field and in my field notes. A locality with n s-surfaces has yielded $(n-1)$ tersections to this synopsis. Area 1 is excluded in order to make it possible compare this synopsis with the previous. In my earlier papers (Lindström 7, pp. 14—15, 1958 *a,* p. 15), I have regarded the second kind of β synopsis avouring older β intersections. However, I have discovered that this reason- contains an elementary fault. All that can be said about β of adjacent

s-surfaces as compared with β from all *s*-surfaces of a locality is that the form
kind will tend to represent folds with a smaller wave-length than the latte
and that it may also contain a greater proportion of true fold-β, whereas th
β assemblages for whole localities will comprise a relatively great number
random β.

The third kind of β data that are dealt with here consists of the absolu
β-maxima of all the locality diagrams (D 2). The position of the absolu
β-maximum (the greatest density of β projection-points) of each locality dia
gram was determined with a 1 % counter, and the median point of the 1
field was taken to represent the maximum. Even in this case, only areas 2—1
are involved. In some diagrams there was not one maximum but two that we
equally strong.

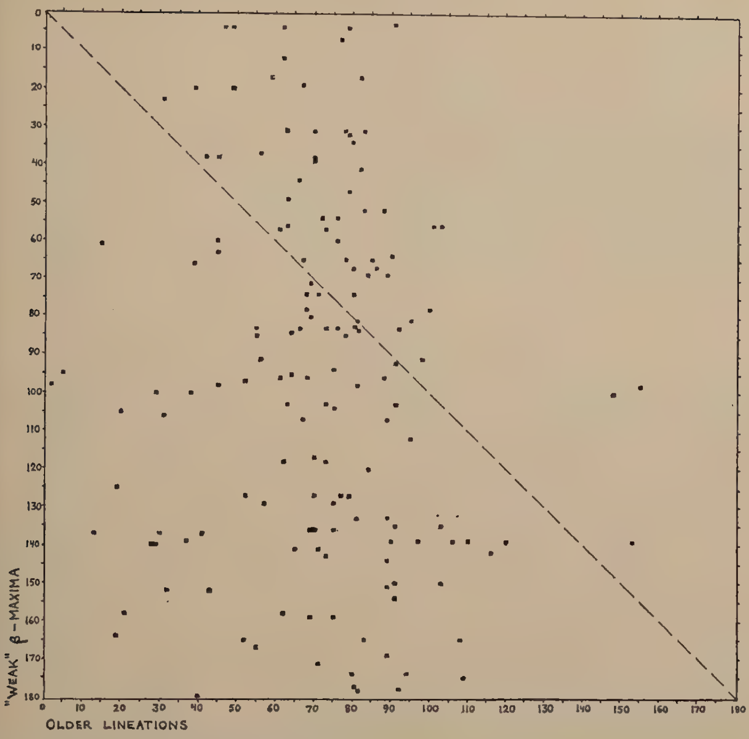
A maximum in the total diagram for all β (D 1), may consist of thre
categories of β: *1.* β belonging to strong local absolute maxima, of 20 β an
more (all such maxima are brought together separately in D 9). *2.* β belongin
to weaker local absolute maxima, with less than 20 β in 1 % of diagram are
(all these maxima are compiled in D 10). *3.* β not belonging to local absolu
maxima, but occurring nonetheless with about the same orientations in a gre
many localities. In my areas, category 1 represents mainly B-tectonites in th
sense of Sander, category 2 mostly S-tectonites (with sub-parallel surfaces). I
an S-tectonite, β is most unstable; little rotation of only a few surfaces is neede
in order to dissolve a concentration of intersections and create a new one wi
another orientation.

The highest of the above categories, 1, requires a more penetrative deform
tion than category 2 that, in its turn, requires a stronger deformation than th
lowest category, 3. A deformation that could give rise to any of the high
categories would give rise to even more numerous instances of the low
categories. If a strong β-maximum (category 1, D 9) is relatively young, the
should also be weaker ones (category 2, D 10) with the same orientation,
well as persistent single β. In other words, a relatively young concentration
D 9 should be matched by at least an equally strong concentration in D 10 ar
thus also in D 2 (D 9 + D 10), and a maximum with at least the same relati
strength in D 1. Concentrations that are relatively best represented in D 9 a
likely not to be relatively young, but rather old, the weaker and less stable
concentrations created by the same phase having been destroyed.

In the same way, orientation groups that appear better in D 10 (weak
maxima, of S-tectonites, category 2), as well as in D 2 in general, than in D
should tend to be relatively old, compared with maxima that appear relative
best in D 1, which maxima are largely made up of the more or less singly o
curring, but persistent β of category 3.

Comparisons of D 1 with D 2, and of D 9 with D 10, will thus give clues
the relative ages of the axes. What has here been said about D 1 as compar
with D 2 is also true for D 6.

Slight changes of *s*-surface orientations in a tectonite with roughly parall
s-surfaces (S-tectonite) may reorient the intersections, β, very strongly, where



ig. 7. C. R. strikes of older lineations and associated local β-maxima in cases where the latter are weak. *Cf.* explanation of text-fig. 6.

eations that are imprinted in the surfaces are hardly affected at all. A β nd in an S-tectonite is therefore much less stable than a lineation trend. iere the dominant β trend diverges from the dominant lineation trend, β is st likely to be the younger of the two. S-tectonite conditions are generally proached in my areas. The β diagrams will therefore favour relatively young s, compared with the lineation diagram (D 3).

The correlation diagrams (text-fig. 6—9) confirm this conclusion. Text-fig. hows that older lineations (see next page) largely are independent of the naxima of the localities where they occur, if these β-maxima are weak (less n 20 β in 1 % diagram area, mostly approached S-tectonites). Younger eations, on the other hand, show an appreciable correlation with the weak naxima, a correlation that may amount to near-parallelism (text-fig. 9). h younger and older lineations tend to coincide with strong β-maxima β or more in 1 % diagram area, mostly B-tectonites). A comparison of :-fig. 6 and text-fig. 7 will confirm the assumption that B-tectonite β are re likely to survive later deformations than the β of S-tectonites. The strong naxima are much better correlated with the older lineations than are the k β-maxima.

The reasoning in this chapter has lead to the following principles that appl under the special conditions found in my areas:

1. The synopsis of individual β (D 1, and D 6) tends to favour younger axe than does the synopsis of local β-maxima (D 2).

2. The synopsis of weaker β-maxima (D 10) tends to favour younger axe than does the synopsis of stronger β-maxima (D 9).

3. The synopses of β tend to favour younger axes than does the synopsis o lineations (D 3).

Older and Younger Lineations

A small overturned fold may intersect a set of parallel lineations obliquely If the lineations are not due to a secondary cleavage intersecting the fold limbs and if they are deflected by the fold and can be followed round its hinges, the should be older than the fold. Imaginary smoothing out of the fold woul restore the lineations to their original condition of straight lines (*cf.* text-fig 18 & 19, and Lindström 1958 *a*, fig. 2, p. 12). 241 such older-younger couple have been recorded so far, from areas 2—12. The older components of thes couples are brought together in D 4. The younger components will be foun in D 8 that has not been counted out. The correlation diagram, text-fig. 5 shows the strikes of the older and younger lineations as they occur together From this diagram alone it is evident that there are different deformatio phases with different lineation orientations as a result, for if both older an younger lineations had been the result of one and the same phase, lineations o one direction would have been now older, now younger than those of othe directions, and the half on one side of the diagonal would consequently hav been the mirror image of the half on the other side.

We have in D 4 a synopsis that is specially selective for older lineations, an in D 8, one that is selective for younger. The diagram for all lineations, D 3, i neutral in this respect. From this, one may deduce the following two principle that are added to the three of the preceding chapter:

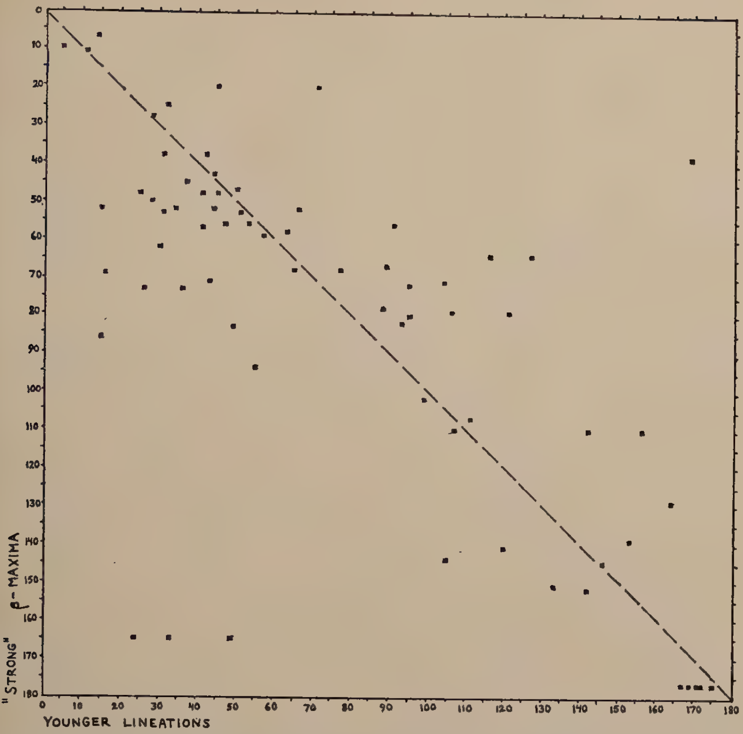
4. The synopsis of younger lineations (D 8) tends to favour younger axe than does the synopsis for all lineations (D 3).

5. The synopsis for all lineations tends to favour younger axes than does th synopsis for older lineations (D 4).

The Age-relationships of the Main Axial Strikes

The strongest maximum for older lineations (D 4, pl. 2) has the strike C. R 67—69 (*cf.* table 1). In the diagram for all lineations (D 3, pl. 2) the stronges maximum strikes in C. R. 56. Axes striking in C. R. 56 are thus younger tha others with strikes in C. R. 67—69, according to principle 5, above.

Younger lineations (D 8, pl. 3) have various strikes, but there is not an marked preference for the direction C. R. 56. The chief lineation maximu



ig. 8. C. R. strikes of younger (deforming) lineations (*cf.* text-fig. 5) and associated local β-maxima in cases where the latter are strong. *Cf.* explanation of text-fig. 6.

s therefore not represent one of the youngest tectonic axes of the areas (*cf.* nciple 4, p. 30). This circumstance is borne out also by the correlation gram for older and younger lineations, text-fig. 5. There are some young ations about C. R. 56, but they are only younger than a rather narrow up of old lineations striking in C. R. 70—90. Old lineations about C. R. 56 e their corresponding younger lineations spread over various strikes.

n the diagram for all individual β intersections (D 1, pl. 2) the strongest ximum occurs in C. R. 77. This is younger than the lineation maximum in R. 56 (principle 3, p. 30), unless the diverging β and lineations groups are genetic. If they were this, there should be some correlation between them he diagrams, text-figs. 6—12. There is not any such correlation; instead, diagrams show that correlated β and lineations tend to be very nearly allel (*i.e.*, to cluster about the diagonal of each diagram, see particularly -figs. 10 and 11).

he inferred age-relation between the main lineation maximum and the n β maximum can be corroborated in an independent way, through ap-ng principle 1 (p. 30) on a comparison between the β diagrams. According his principle, maxima that appear better in the diagram for local β-maxima 2, pl. 2) than in the diagrams for individual β (D 1, D 6) should be older than those for which this is not the case. The strongest maximum in D 2 is a compound maximum in C. R. 53—61, and this maximum does not have nearly the same importance in D 1 and D 6. Consequently, it should be older than the chief maxima in D 1 and D 6. It remains to prove that the β maxima about C. R. 53—61 have anything to do with the lineations about C. R. 56. Text-figs. 10—12 will prove this point, since they show a definite tendency for lineations and β-maxima to coincide about the strike in question. (There is possibly a tendency for the lineation strikes to be deflected 3—5° anti-clockwise from the strikes of the associated β maxima.)

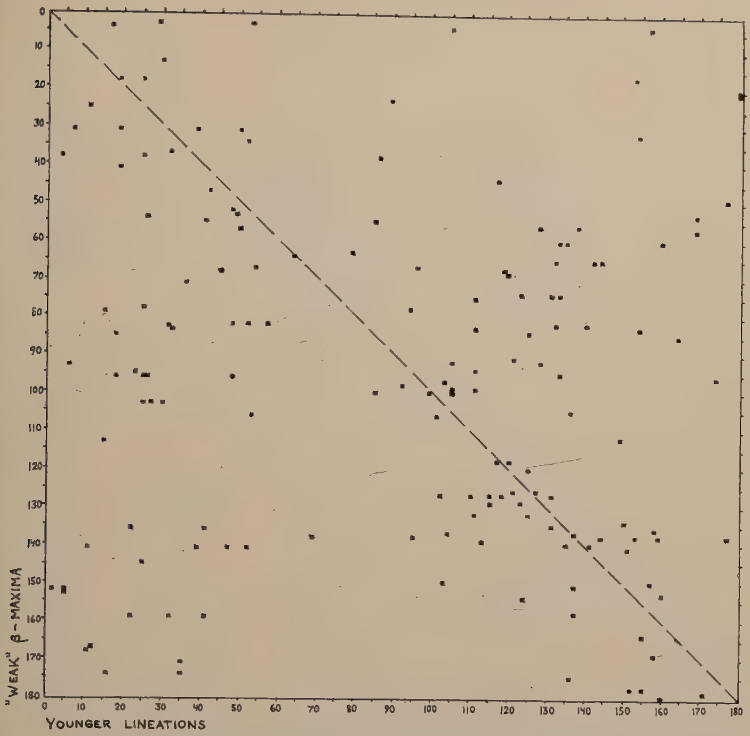
It is also significant that the concentration in C. R. 53—61 contains a greater proportion of the stronger local β-maxima (D 9, pl. 3) than any of the other concentrations in D 2 (*cf.* principle 2, p. 30).

To sum up, the results that appear to be best documented are that a group of lineations that strike in C. R. 67—69 are older than lineations of the dominant trend that is in C. R. 56. Local β-maxima striking in C. R. 53—61 are probably syngenetic with the dominant lineations. The chief concentration of β, in C. R. 77, is younger than the lineations and β about C. R. 56.

The deductions in the following are generally regarded as less secure than the ones formulated above. A few are most uncertain.

The next strongest maxima in the diagram for relatively old lineations (D 4, pl. 2) strike in C. R. 81 and C. R. 76. These maxima represent older tectonic axes than the main lineation maximum in C. R. 56, according to principle 5 (p. 30). It is also possible, however, that according to the same principle they are older than other, slightly stronger, old lineation maxima in C. R. 67—69, for compared with the latter they have an unduly feeble correspondence in the total lineation diagram (D 3, pl. 2). Lineation trends would then have been formed in the following order, beginning with the oldest: C. R. 76—81, C. R. 67—69, C. R. 56. (There are in the diagram, text-fig. 5, no younger lineations in about C. R. 67—69 that are connected with older lineations in about C. R. 76—81. A hypothetical explanation for this may be found in a circumstance that will be dealt with further on, viz. that there are independent reasons for regarding the lineations in C. R. 67—69 as a transport-parallel fabric, entirely penetrative where it occurs, and thus eliminating older structures. The possibly corresponding transport-normal lineations, in approximately C. R. 155, are indeed younger than lineations with strikes in about C. R. 81, as will be seen in text-fig. 5).

The diagram D 2 (pl. 2) for local absolute β-maxima has, as already mentioned, one of its two strongest maxima in C. R. 53—61, and this maximum i apparently syngenetic with the lineation maximum in C. R. 56. The other o the strongest maxima in D 2 strikes in C. R. 82, and is younger than th previous according to principle 2 (p. 30), since it consists of a greater propor tion of feebler local maxima (compare D 9 and D 10, pl. 3). It is also th younger according to principle 3. D 2 has two other strong and distinct maxima in C. R. 104—109, and in C. R. 139. Both are much better represented in th selection of the feebler local absolute maxima (D 10, pl. 3) than in the selec



ig. 9. C. R. strikes of younger lineations and associated local β-maxima in cases where the latter are weak. *Cf.* explanation of text-fig. 6.

n of stronger maxima (D 9, pl. 3) and will thus according to principle 2
. 30) be younger than the maxima that are concentrated about C. R. 53--61.
the four main direction-groups of local β-maxima that have been mentioned
e, the one in C. R. 139 may be the youngest. This conclusion is based on
correlation diagrams, text-figs. 11 & 12. The only group of local β-maxima
t in these diagrams appears to be almost indifferent as regards the strikes of
ociated lineations has the strike C. R. 135—143. This could be due to over-
nting of lineations on the β fabric, if the β fabric were strong enough to
hstand such a process without being dissolved. As it is, the markedly con-
trated local β-maxima about C. R. 139 are almost exclusively feeble (D 10,
3), and belong to approached S-tectonites. It is thus more likely that they
e been overprinted on a lineation fabric, than *vice versa*. Contrary to the
er three main direction-groups of local β-maxima, they have been over-
nted on lineations of all orientations, without any clear preference. This
kes them most likely to be the youngest. With the same reasoning, based on
t-fig. 11, one may guess that local β-maxima in C. R. 103—105 may tend
be younger than those in C. R. 80—84, since the latter have a more re-
cted range of associated lineations than the former. The conclusion will then
that the main direction-groups of local β-maxima

were formed in the following order, beginning with the oldest: C. R. 53—61, C. R. 82, C. R. 104(—109?) C. R. 139.

If the youngest of the main orientation-groups of β-maxima is the one that strikes in C. R. 139, this group is still relatively old as compared with several of the main trends of individual β (D 1 and D 6, pl. 2). Maxima in C. R. 36—37 (D 1, D 6), C. R. 107—109 (D 6, D 1) 119—122 (D 1, D 6), and C. R. 130 (D 1) all tend to be younger than the local β-maxima in C. R. 139, since their importance compared with the latter is greater among individual β than among local β-maxima (*cf.* principle 1, p. 30). The age-relationships within the mentioned sequence of maxima for individual β cannot as yet be determined, even tentatively.

Furthermore, according to principle 1 (p. 30) it is most likely that the main β maximum striking in C. R. 77 (D 1) is younger than the local β-maxima about C. R. 139 (D 2). By the same principle, it will also be younger than the local β-maxima in C. R. 104—109 (D 2) tend to be, since the C. R. 77 maximum compared with the latter is the stronger in D 1, but the weaker in D 2.

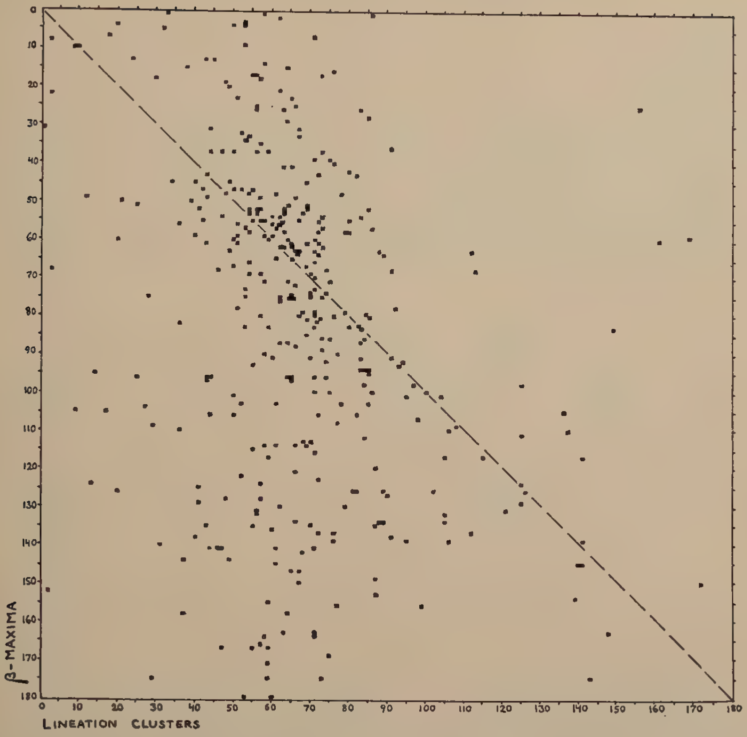
The individual β for adjacent *s*-surfaces (D 6) have one of their two strongest concentration peaks in C. R. 69. Like the maximum dealt with in the previous paragraph, this one will according to principle 1 mainly be younger than local β-maxima about C. R. 139 and C. R. 104—109. Since it corresponds to an even lower concentration of the local β-maxima of D 2 than the maximum in C. R 77 does (0.75 % as against 1.5 %), it may by the same principle be younger than this maximum (there is in D 2 a maximum of 1.75 % that strikes in C. R 68 and thus nearly coincides in strike with the maximum in C. R. 69 that is being discussed. However, the plunges of the two maxima are not the same)

If these considerations are true, the younger of the main concentration peaks for individual β will have originated in the following order, beginning with the oldest (olde than the following are local β-maxima about C. R. 139) C. R. 109, C. R. 77, C. R. 69. To this group of young β-maxima belong also those striking in C. R. 119—122 and C. R. 130.

Detailed Analysis of Part of the β and Lineations

When the point frequency gets very great, as it is in parts of the diagram D 1 and D 3 (pl. 2), it may be rewarding to make the counting out with an even greater precision than one can obtain with the 0.25 % counter. With the 0.25 % counter, maxima that are less than 5° apart will tend to be regarded a one maximum.

For an experiment in detailed counting out, an orientation cell limited b the strikes C. R. 49 and C. R. 70 was selected. The outline of the cell appear in D 7 pl. 3. The counting out of the β and lineations occurring within thi cell on the different total areal diagrams was then carried out over a millimete



g. 10. C. R. strikes of associated lineation clusters (≥ 5 lineations with maximum diver-nce about 10°) and local strongest β-maxima (including both the strong and the weak category text-figs. 6—9). Each point refers to the β-maximum and one lineation cluster at a particular locality. Broken diagonal line = line of coinciding strikes.

id with numbered vertical and horizontal columns and the figures arrived at ere written on a table representing the grid, in the same way as the counting-it figures are written down on the counting out over the ordinary grid used r D 1—D 8, and similar diagrams. In this way an infinite number of points th identical positions can be counted. The number of points within each milli-eter square was counted in all the areal diagrams, and summed up in the ble. The densities found are illustrated by isarithms in text-fig. 13.

In the diagram for lineations (text-fig. 13: 2), the strongest concentration curs in the lowest portion, with the strike C. R. 53. One can discern strong, ore or less continuous concentrations about C. R. 55, C. R. 60, and C. R. 66. here is an isolated nearly horizontal concentration peak in C. R. 68. The only o of these concentrations that appear when the counting out is done with a 25 % counter, as in D 3, are the ones in C. R. 55 (C. R. 56 in D 3) and C. R. (C. R. 65 in D 3). One of the concentration fields, the one about C. R. 66, incides tolerably well with the strongest maximum for old lineations, in D 4. If the pattern in text-fig. 13: 2 is analyzed in detail, the results will of course unreliable. The broad features are, however, in any case worth remembering, since they show that the lineation orientations in C. R. 49—70 are grouped about several maxima that are not rendered exactly in D 3, pl. 2.

The β distribution, in text-fig. 13: 1, has its strongest maxima in C. R. 50, C. R. 59, and C. R. 64. This picture coincides only to some extent with the one obtained in D 1. The pattern of β in text-fig. 13 is strikingly different from that of the lineations; only in two places is there a marked similarity. There is a minor β concentration nearly corresponding to the lineations in C. R. 66, and the β and lineation maxima in C. R. 59—60 are as close together as almost to coincide.

Directions of Tectonic Movement

In tectonites with sub-horizontal *s*-surfaces it is probable that linear structures of the kinds recorded in this paper should mostly be either parallel or normal to the tectonic movement under which they were formed. Local deflexions of movement, local influence by pre-existing fabrics, and ever-present errors of recording cause the ideal condition to be only approximately fulfilled in the samples.

A direction-group of linear elements could also constantly make an angle between 1° and 89° with the direction of the chief movement that formed the group. This could happen if the direction of medium stress during the movement were considerably inclined in one and the same sense over large areas, a most unlikely condition. It could also be due to anisotropy, either in the moved material or in its substratum. This must be dealt with somewhat specially.

The Archean basement is exposed in my areas 4 and 5. The main strikes of the Archean about area 4, Allesjaure, are about N—S and N 30° E, according to H. Johansson's map in Ödman 1957, p. 46. The strongest maxima for linear elements in the Caledonian tectonites that rest on the Archean (Lindström 1958 *a*, D 16, D 17, & p. 18) strike in N 56° W. In area 5, Haukajaure, the Archean (Lulemusjuovatjårro) has the topographic strike N 52° W. The Caledonian tectonites next to the basement have their linear elements striking mainly in the directions N 56—57° E, N 66° W, N 37° W, and N 27° E (D 30, D 31, D 37—40 in Lindström 1958 *a*). Thus there is no evidence for any higher degree of structural control exerted by the basement, even in the areas where such a control would be most probable.

Movements that came after the main trend of lineations had been imposed met with a very strong anisotropy in the material itself. This anisotropy, as well as others, could easily have affected the trends of subsequent linear elements. However, the lineations were largely imprinted in *s*-surfaces, and the whole retained its character of essentially parallel and sub-horizontal S-tectonites. This must have reduced the controlling effect that the lineations might have had on later fabrics, since the *s*-surfaces were still largely free to rotate about any axis that was normal or parallel to a chief movement.

The main groups of linear fabric elements are here regarded as being either normal or parallel to a major tectonic movement. For the reasons stated above, this may be only a rough approximation in some cases.

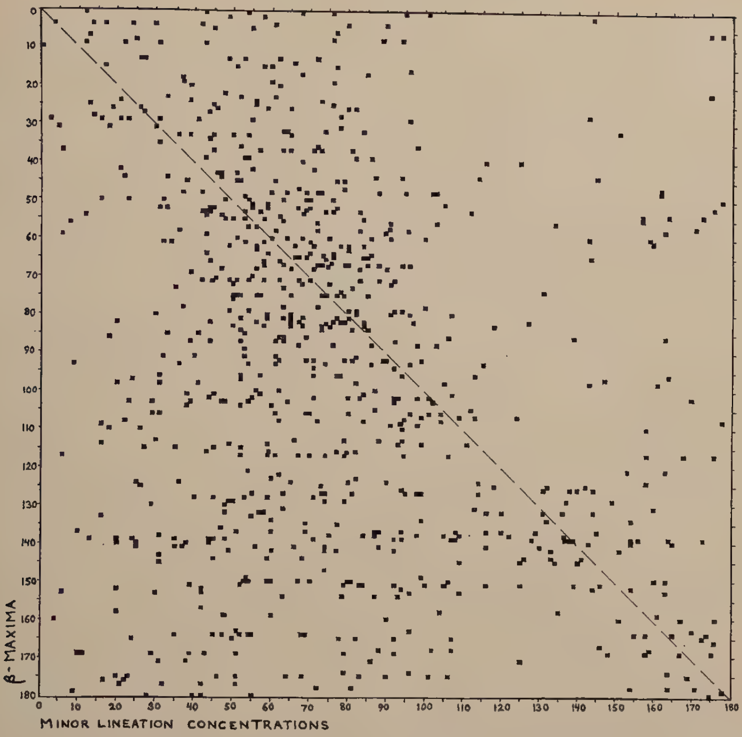


Fig. 11. C. R. strikes of associated minor lineation clusters (≥ 2 lineations with maximum divergence about 7°) and local strongest *β*-maxima. *Cf.* explanation of text-fig. 10.

Certain fold structures tend to have an axial symmetry, *i.e.*, the *s*-surfaces
e all parallel to one line, but otherwise they tend to be randomly oriented.
hese folds are interpreted as parallel to a main tectonic movement (*cf.* Lind-
röm 1958 a, pp. 32—39). They are akin to the slickenside *Rillung* described
d figured by Engels (1959, pp. 97—98). (It must be emphasized, however,
at none of the structures that are dealt with in this paper are slickensides).

The most instructive folds of the kind referred to were found in the Kartim-
re area (3) (Lindström 1957, p. 11, pls. 1, 2) and strike in N 50° W (C. R.
). Structures with an approach to this type of symmetry are rather common
all the areas. They mostly strike in about WNW—ESE (C. R. 50—80). Text-
. 4 shows a cross-section (deformation plane) of a typical instance with the
ike C. R. 59—239. These structures are invariably parallel to striations of
e kinds briefly described above, on p. 24.

Conglomerate pebbles and agglomerate inclusions have been identified in
eas 8 and 9—11. They are invariably stretched, mostly with 500—1000 per
nt deformation along their longest and shortest axes. The shortest axes are
rmal to the schistosity, or as a rule almost vertical. A few of the lineations
corded in the areas mentioned above were stretched pebbles. I have thus
ne recording of the directions of the longest axes (D 27, pl. 3), mostly from

area 11 (Lommi), where recognizable conglomerates and agglomerates are the most common. There is in D 27 a sharp nearly horizontal cluster for stretching in C. R. 67 and a more diffuse group about C. R. 55. The variation extends mainly between C. R. 35 and C. R. 85. There has evidently been a chief movement within the tectonites, parallel to the stretching. However, this must have been combined with a movement (transport) of material relative to the basemen of the overthrusting (*cf.* also Strand 1945). The stretching is associated with, and passes into, parallel striations of different kinds.

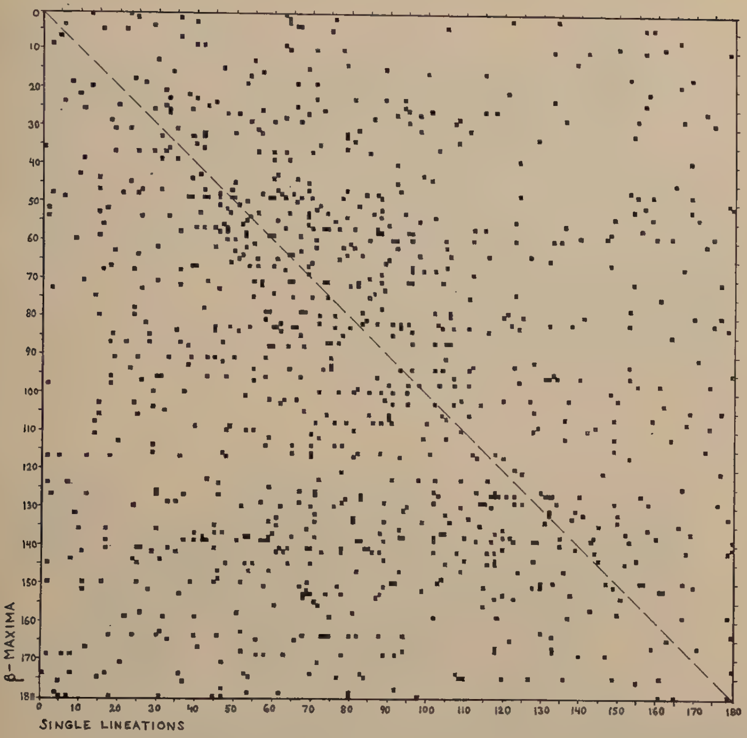
Linear structures that are parallel to the main direction of movement might arise in zones of very strong movement under considerable hydrostatic pressure (*cf.* Lindström 1958 *a,* p. 39). In agreement with this hypothesis, the fabrics that have been discussed in the last two paragraphs are completely penetrative where they occur.

Folds will mostly be overturned in the direction of flow of the rocks. 720 of the lineations recorded in areas 3—12 have been small folds with an overturned limb. In each case the direction of overturning has been noted. All these data are summarized in D 11, pl. 3. The diagram shows the strikes of the small folds plotted along the periphery. The direction of overturning is clockwise from any given strike. A fold that is plotted at C. R. 60 is thus overturned toward C. R. 150, and one that is plotted on the opposite side of the diagram, at C. R. 240, is overturned toward C. R. 330. If the contents of the diagram are rotated 90° clockwise, the diagram will immediately show the main directions of the movements that caused the folds to be overturned. The strike rose in the middle of the diagram is based on the same data as the plots along the periphery. For its construction the strike data have been counted out with a counter cell of 3°. Thus for instance the frequency culmination at C. R. 51 comprises folds that strike in C. R. 50—52 and are overturned toward C. R. 140—142.

Nearly all possible directions of overturning occur, but north-westerly directions are in general poorly represented, in all the areas.

If two sub-equal high frequencies match one another in exactly opposite directions, it is possible that the fold trend, which is thus proved to be indifferent as regards sense of overturning, is parallel to the corresponding direction of chief movement. However, the strike rose does not give evidence of any such case. Instead, there are several cases of folds with certain strikes being predominantly overturned in the same sense. Such folds are likely to have been formed normal to a direction of chief tectonic movement, the sense of which they indicate.

It appears that dominant movements were in directions nearly parallel to the mountain chain (rather surprisingly, one may be entitled to say). Frequency culminations in C. R. 51, C. R. 70, and C. R. 275 give the main proof for these movements (toward C. R. 141, C. R. 160, and C. R. 5, respectively). The finding of movements toward C. R. 141 and C. R. 160 confirms an observation by



g. 12. C. R. strikes of associated single lineations (diverging at least 5° from other lineations) and local strongest β-maxima. *Cf.* explanation of text-fig. 10.

slie (1941, pp. 54 & 293) that was put into doubt in Lindström 1958 *a* . 59).

Other important frequency modes occur in C. R. 313, C. R. 322, and C. R. 1 (with movements toward C. R. 43, C. R. 52, and C. R. 71, respectively). The overturned small folds cannot be correlated with other fabric data with y degree of certainty. However, as regards their strikes, they agree better with D 1, D 2, D 6, pl. 2) than with lineations in general (D 3 pl. 2) (see table 1, 58), which may be explained by the circumstance that like β, they are due rotations of *s*-surfaces, but on a considerably smaller scale and with generally newhat different results.

The frequency mode at C. R. 51 may perhaps be correlated with the β maxim in C. R. 50 (D 1, pl. 2, & text-fig. 13: 1) rather than with the lineation ximum in C. R. 56. The mode at C. R. 70 may correspond either to the very ng β maximum in C. R. 69 (D 6, pl. 2), or to the very old lineations in R. 67—69 (D 4, pl. 2), or partly to one and partly to the other. As for the de at C. R. 275, it does not have any well-defined counterpart either in the grams for β or in the total diagram for the lineations.

From the data that have been considered in this chapter, one may conclude t a good many if not most of the lineations of the dominant trends in C. R.

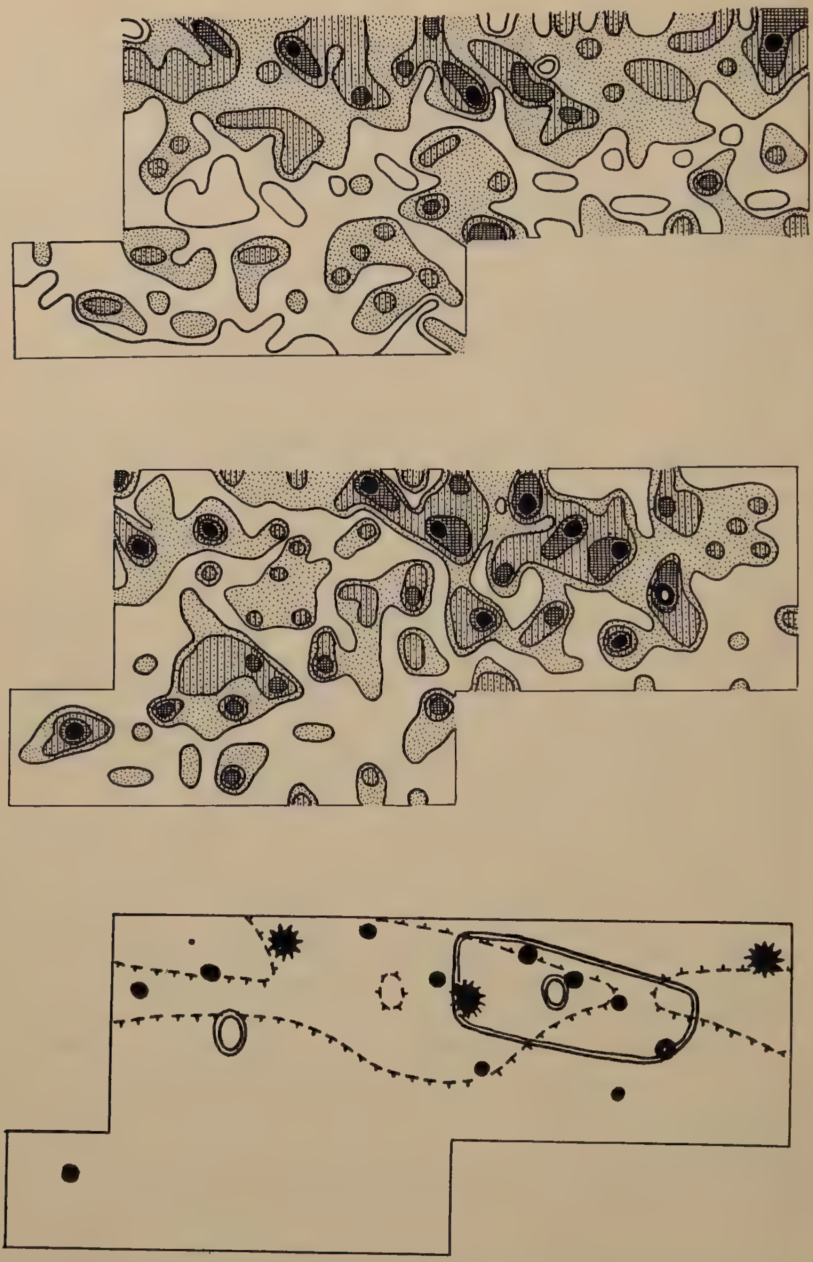
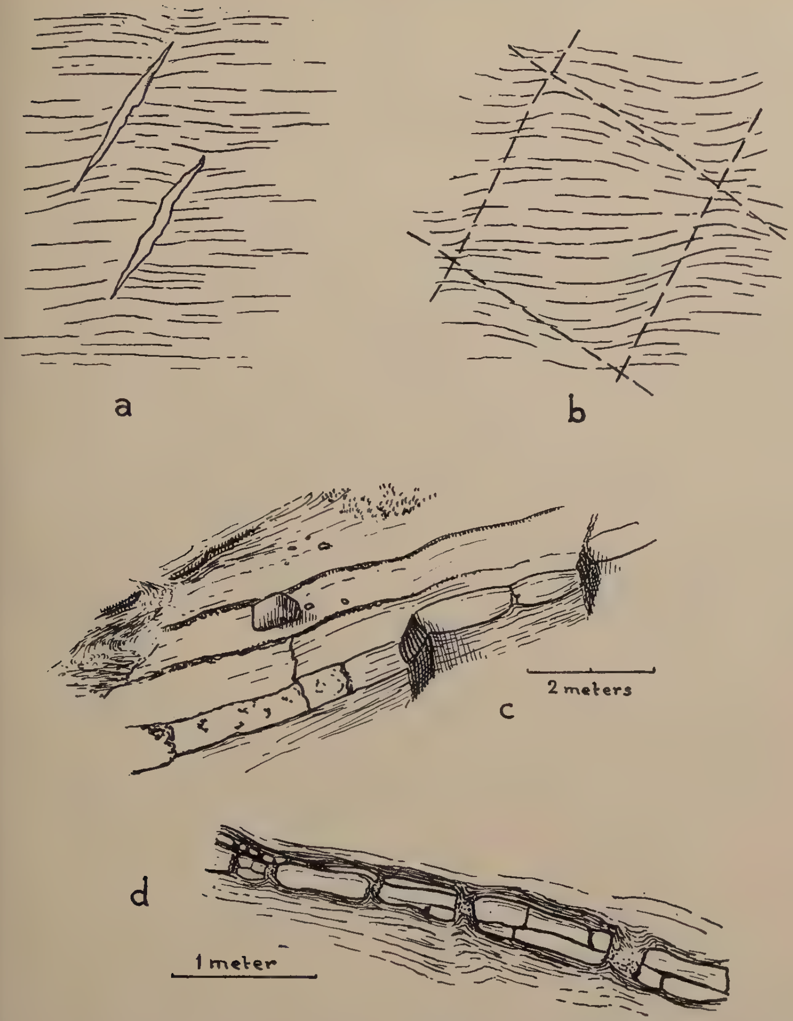


Fig. 13. Detailed counting out of all β and lineations for all areas. Frequenciesin 1 mm^2 within the cell of orientations outlined in D7, pl. 3. — *1.* β frequencies. Isarithms for 4—6—8—10—12 β in 1 mm^2. — *2.* Lineation frequencies. Isarithms for 3—4—5—6—7 lineations in 1 mm^2. — *3.* Synopsis of 1 and 2 with corresponding portions of D1 and D3, pl. 2. Round black spots = lineation maxima of 2. Black starlets = β maxima of 1. Double lines = frequency contours in lineation diagram, D3. Toothed broken lines = frequency contours in diagram for all β, D1.



14. *a* & *b*. Relations between lineations striking about C. R. 56, and boudinage cracks, en on *s*-surfaces. Vastenluspen area (8). Sub-parallel lines-lineations. Broken lines = trends oudinage cracks that fail to break through phyllitic skin of boudins. Diagrammatic. — *c*. linage of garben-schist in soft phyllitic mica-schist. Two sets of boudinage cracks, one sting of narrow, a little irregular cracks, normal to plane of picture, the other consisting of rather straight and wide, vein-quartz filled cracks, parallel to plane of picture. Area 8 tenluspen), Puoltaketjejokk, tributary from N. Semidiagrammatic, after photograph. Look-48° E (C. R. 178). — *d*. Boudinage of dolomite in green-schists. Area 9 (Jaurekaska) 1300 rs S of "e" in "Rasteluokt*e*" (ordnance map). Looking N4° W (C. R. 126). After photographs and field sketch.

55—67 were formed parallel to a chief tectonic movement. Some of the mai direction-groups of β intersections might be correlated with small folds tha were formed normal to other directions of chief movements. If the suggeste correlations are true these chief movements should belong to later phases, sinc the β concentrations are mostly younger than the lineation trend.

Fracture Cleavage and Slip Folds

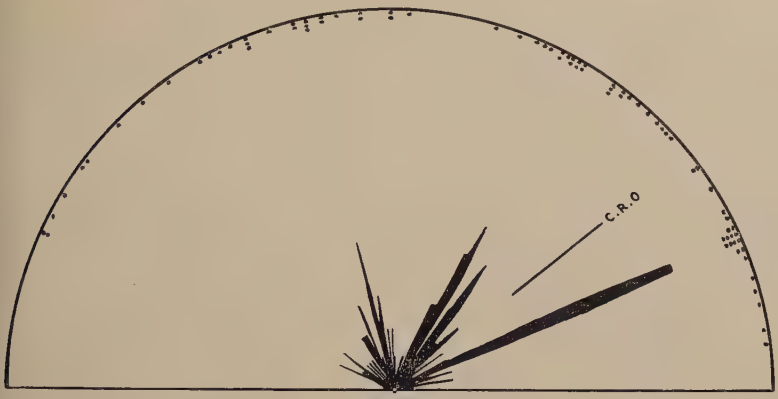
It is a trivial observation that folds may occur along intersections betwee fracture-cleavage and other kinds of lamination. Fracture-cleavage with accompanying folds is met with but sparsely in most of my areas and does no contribute significantly to the total fabric. However, in areas 11 and 12 the are common enough to be well worth a special treatment. Text-figs. 20—2 illustrate what I am referring to as fracture cleavage.

The folds and the fracture-cleavage were formed after the laminations. Th laminations may have varied in orientation, before the fracture cleavage wa imposed. According to an hypothesis, the attitude of the fracture-cleavage wil tend to be constant, rather than to vary with the orientations of pre-existin *s*-surfaces. Consequently, the intersections and the accompanying folds ma tend to vary in a more or less random way within the plane of the fracture cleavage.

The hypothesis has been developed particularly by Weiss & McIntyre (1957 see especially fig. 12, p. 598). Before one deals with the instances from th Lommi and Balvatnet areas, it may be worth remarking that the diagrams give by Weiss & McIntyre do not prove their hypothesis for the area they are discussing. According to the hypothesis, the folds (B′) should have their chie maximum at the intersection between the predominant orientation of the pre existing lamination (S) and that of the fracture-cleavage (S′), or at the pol of the great-circle through πS and πS′. If one may judge from the diagrams o fig. 7, p. 588, in the paper of Weiss & McIntyre, B′ diverges from this expected position by about 45°.

The fracture-cleavage in the Lommi area (11) has mostly a low dip towar NW. In the Balvatnet area the dips are also low, but more irregularly dispersed. The fracture-cleavage planes very frequently show minute parall phyllitic striations that are hypothetically regarded as parallel to the motio on the cleavage-planes. The most probable deformation plane in each instanc would then be parallel to these striations and normal to the cleavage-plane. is defined in projection as the great-circle that runs through the striation-pol and the pole of the cleavage. D 12, pl. 3, shows the instances of striated fracture-cleavage that have been recorded in areas 11 and 12. Broken lines indicat the hypothetical deformation planes that connect striations (ringlets) with corresponding cleavage poles (points). It appears that the strikes of the deformation planes are rather uniform, despite variations in the orientation of bot cleavage and striations.

The axes of internal rotation that would be normal to the hypothetical d



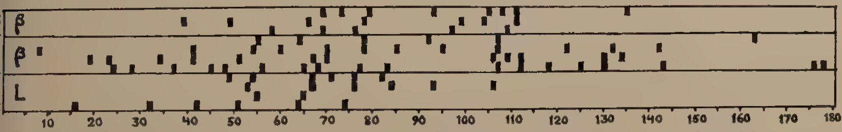
15. Strikes of 79 boudinage cracks, areas 7—12. Each point along the periphery rep-
ts the strike of a single crack. The rosette in the middle was obtained by a counting out
of the data about every degree of the periphery with three degrees as the counter cell.

ation planes are indicated by crosses in D 12. These hypothetical rotation have the same range of orientation as the apparent rotation axes of folds are inferred to have been formed by slip on cleavage-planes (marked by ted ringlets). Thus, the observed slip folds are most ely not to be random in their orientations, but to be ghly normal to the direction of slip on the fracture- avage. The slip seems mostly to have been toward about C. R. 55. It t be emphasized that it is manifestly younger than the main lineation trend . R. 56 that it distorts in several places.

Boudinage and Other Evidence of Extension

oudinage develops as a consequence of pure tension in a competent bed is jacketed in between plastic beds that flow outward because of compres- normal to the bedding (Ramberg 1955, Lindström 1958 *a*). Boudins, in restricted, original sense of the term, are not subjected to considerable ex- al rotation while they are being formed. Some situations that were ideal he formation of boudins were sketched in Lindström 1958 *a*.

oudinage cracks would not develop normal to a direction of considerable onic transport, but might be formed parallel to such a transport, if material



16. C. R. strikes of concentration peaks of axes in different groups of areas (*cf.* table 2)
ost strip: maxima in diagrams for all β (D18, D21, D24). Second strip: adjacent β (D16
D22, D25). Lowest strip: lineations (D17, D20, D23, D26). Numerals to the left of the table
refer to the areas.

were allowed to flow out normal to the transport direction (this condition w not mentioned in Lindström 1958 *a*, but it is of course essential).

Boudinage might be formed in front of a body pushing forward normal the main orientation of strata, for instance a forcibly rising granitic body, such a thing does occur.

Boudinage could also be formed in material escaping uniformly outwar from under a great, geographically restricted load of some kind (this case do not differ much in principle from the preceding, and was not mentioned i Lindström 1958 *a*).

Another situation that would further boudinage might arise by rotation stresses in a “tectonic lea”. This case may be comparatively rare.

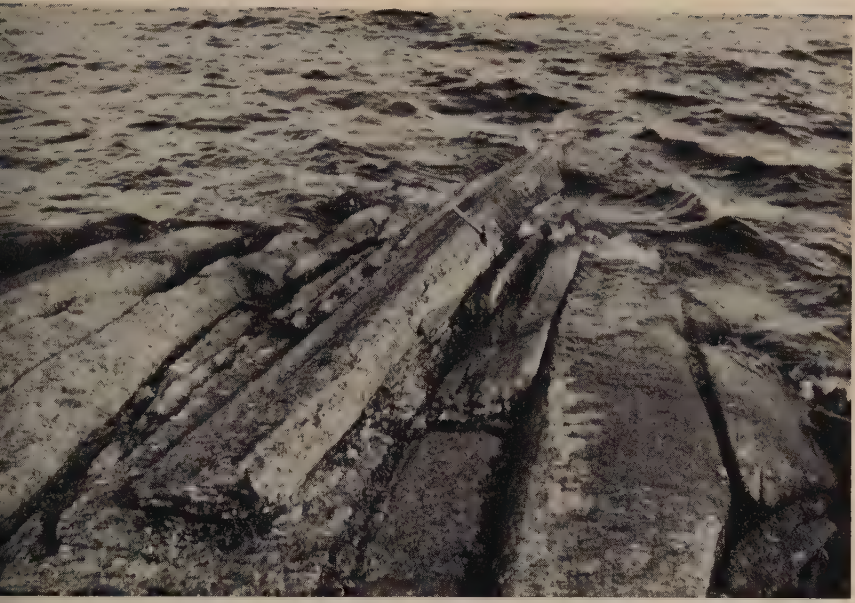
The boudinage effect discussed by de Sitter (1958, p. 281) might occur i any of the cases mentioned. The accompanying parasitic folds in de Sitter diagram and discussion are, if I am not too much mistaken, a special case the ptygmatic folds discussed by Ramberg (1959). de Sitter and Ramberg sho in a convincing way that boudinage *may*, indeed, develop parallel to folds a certain kind.

A good many instances of boudinage have by now been observed by m chiefly in areas 8 (Vastenluspen) and 11 (Lommi). Boudinage very often ha taken place in relatively hornblende-rich beds in soft, more or less carbonat phyllites. Calcite marble in black schists, or coarsely crystalline, thick-bedde beds in more fine-grained, laminated marble, or dolomite marble in gree schists, have also been observed to be boudinaged in a magnificent way.

Boudinage cracks that intersect one another at about right angles are ea to study at several localities along the Puoltaketjejåkk and its tributaries, i area 8. Wegmann (1932, p. 479) has referred to instances of this kind fro Bastogne, and leaves the question open, whether the two sets of cracks deve oped at different times, or not. Pilger & Schmidt (1957, p. 44) also mentic rectangular boudinages from the Ardennes, and liken them to chocolate tablet but do not offer any interpretation.

Coe (1959) has written an illuminating paper on boudinage in West Cor Ireland. He reports on rectangular intersecting boudinage, and evidently co cludes that the two sets of boudinage cracks were formed contemporaneousl assuming the stresses normal to the greatest stress to have been equal (p. 198 I believe, however, that this case would rather give rise to boudinage crac with random orientations. I do not think that Coe's examples of boudinage, described by him, will make his hypothesis justified. He states very clearly (p 194, 195) that the two sets of boudidnage cracks observed by him are n equivalent. I am also rather sure that in some of my instances of rectangul intersecting boudinage, the two sets of cracks developed at different times, sin they are not equivalent in all respects.

The strikes of the boudinage cracks observed in areas 7—12 have be brought together in text-fig. 15. Frequencies are registered for each degr along the periphery. The rosette in the middle is the result of a counting o



17. Tough, thick-bedded mica-schists with about 10 meters long mullions (combined
nd cleavage-mullions), Jaurekaska area (9), about 1.5 kilometers E of outlet of Virihaure.
Looking S80° E.

ee after degree, with three degrees as the counter cell, as I have already
ibed for the fold overturning diagram, D 11.

iere are three well-defined preferred orientations: in C. R. 15, C. R. 115,
C. R. 158. Boudins belonging to the two first of these orientation maxima
to form chocolate tablets in area 8.

the tension in the competent beds had been equally strong in all direc-
the cracks would have been random in their orientations. This happened
amberg's (1955) experiments. The circumstance that the orientations are
andom proves that the tensile stresses at different times were greatest in
in directions, because the enveloping incompetent material tended to flow
ose directions. Normal to a given direction of greatest tensile (or least
ressive) stress would be the direction of the greatest compressive stress
operated in the plane of the beds; this latter stress might at times be
le of forming minor folds normal to the boudinages. We may thus expect
there are penecontemporaneous β concentrations normal to the chief
inage directions, or in C. R. 105, C. R. 68, and C. R. 25. Other β maxima
occur parallel to the boudinage, since boudinage is always accompanied
tation of *s*-surfaces.

xt-figure 14 shows some typical cross-sections of boudins from my areas.
e figure are also shown instances of the relation between boudinage and
ions in the Vastenluspen area. The boudinage cracks belong to the orien-
groups in C. R. 15 and C. R. 115. The lineations belong to the trend

striking about C. R. 56. The figure shows how these lineations are deforme in the mica-schist lamellae nearest to a basic bed subjected to boudinage. T manner in which the lineations have been deflected by the boudinage see to prove that the lineations are older than the boudinage.

A set of deformation structures that are much akin to boudinage occurs area 12 (Balvatnet), in the western slopes of Dorrotjokka, particularly alo the shore of Kvebilok. I am referring to rather closely set tension gashes th are about normal to the foliation and are lanceolate in cross-section. They a filled by quartz fibres that are normal to the walls of the gashes. They are a rule nearly parallel, and strike in N 12—31° E (C. R. 142—161). The arit metic mean strike of seven instances is C. R. 153. It is possible that they co respond to the boudinage maximum in C. R. 158.

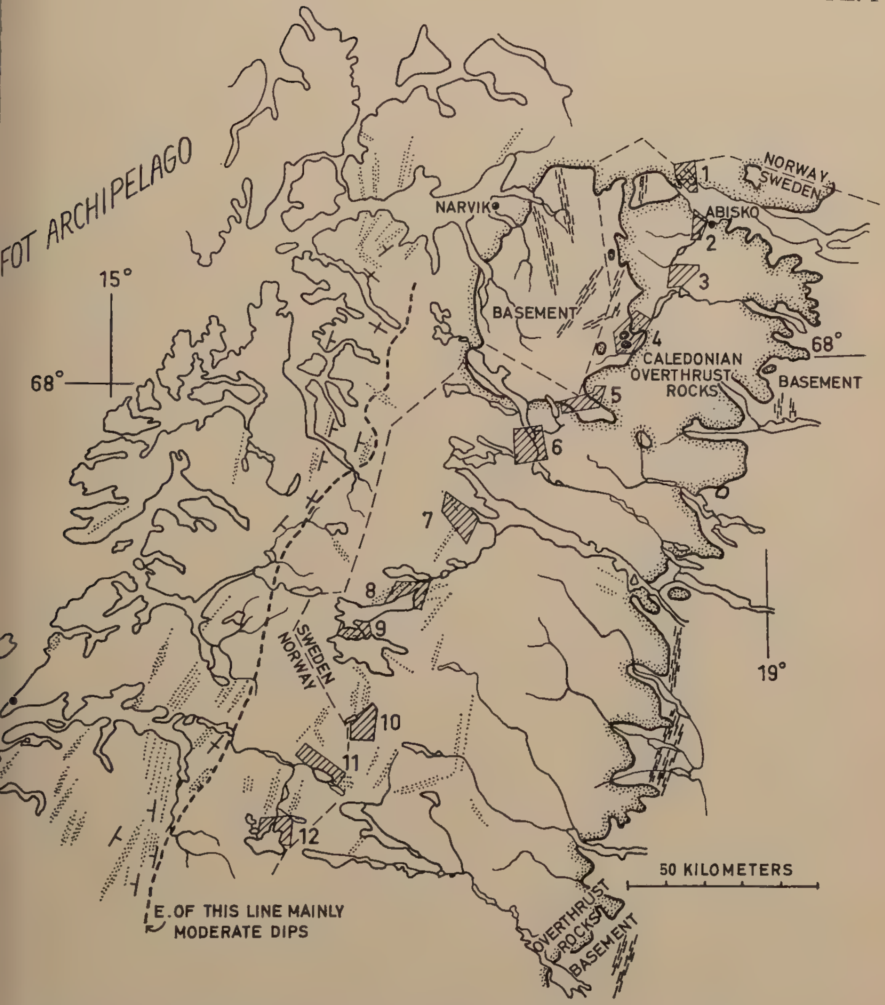
On the N shore of Lake Virihaure, in area 9 (Jaurekaska), there are a fe normal faults striking N—S (about C. R. 130), with downthrow on the weste and partial brecciation on the eastern side. Apart from the tendency to brecc ation, the beds have behaved raher plastically. Similar structures, strikin about N 40° E (C. R. 170) occur in green-schists of Kvebilok, in area 1 where together with folds striking in C. R. 130 they deform joints of differe orientations. Since the joints generally represent the youngest fabric regim of the area, the faulting and accompanying slight flexuring of the foliatio should be of a very young age.

Joints

Joints are among the most important fabric elements from a technologic point of view, but it is very difficult to discuss them genetically. They ma have various orientations relative to other structures, and thus they very fr quently render an otherwise symmetrical fabric triclinic. Probably, they a very often formed after plastic deformation has ceased altogether. Their ag relationships are more difficult to ascertain than those of other fabric elemen particularly if the joints are neither deformed nor mineralized. The joints th are dealt with below belong to this category, with but a few exceptions. Th are mostly perfectly plane and smooth, and they transsect all kinds of roc and structures. I have not found any evidence for movement along these joi surfaces. Competent rocks (greenstones, quartzites) are usually more joint than others.

D 5, pl. 2, is a synopsis of readings on joints in the areas 9, 10, and 12. T joints are represented by their normals. The maxima are listed in table 1. T maxima about C. R. 48 and C. R. 71 are almost exclusively derived from ar 9, the maximum in C. R. 15 is from area 10, and the other maxima are main derived from area 12 (*cf.* D 13—15, pl. 3). It is worth noticing that joi normals contributing to the maxima about C. R. 48 tend to form girdles in t diagram. Two of the major joint groups make a right angle with one anoth (C. R. 42—48 — C. R. 132—138).

PL. I



1. Sketch map, showing locations of areas (diagonal shading). Aligned stipples = major linear trends in overthrust rocks. Dashes = major linear trends in basement.

Plate 2

Iain synoptic diagrams. Schmidt net. *Lower hemisphere.* C. R. O. — 180 = strike of C. R. line. ss at center of each diagram oriented roughly N—S and E—W. *Isarithms for frequencies in 5 % diagram area.*

1. All 43, 837 β of areas 2—12. Isarithms for 0.1 — 0.2 — 0.3 — 0.4 — 0.5 — 0.6 — 0.7 — — 0.9 — 1.0 — 1.1 — 1.2 % in 0.25 % area.

2. All 538 geometric centers of local absolute β-maxima of areas 2—12. Isarithms for ca. — 0.5 — 0.75 — 1.0 — 1.25 — 1.5 — 1.75 — 2.0 — 2.25 % in 0.25 % area.

3. All 7,511 lineations of areas 1—12. Isarithms for 0.25 — 0.50 — 0.75 — 1.0 — 1.25 — — 1.75 — 2.0 — 2.25 — 2.50 — 2.75 — 3.0 % in 0.25 % area.

4. 241 relatively old lineations of areas 2—12. Isarithms for 1 — 2 — 3 — 4 — 5 — 6 — 7 — 9 — 10 poles in 0.25 % area.

5. 1 239 joint normals of areas 9, 10, 12. Isarithms for 0.25 — 0.50 — 0.75 — 1.0 — 1.25 — — 1.75 — 2.0 — 2.25 — 2.50 — 2.75 — 3.0 — 3.25 — 3.50 % in 0.25 % area.

6. 6 558 β of adjacent *s*-surfaces in areas 2—12. Isarithms for 0.25 — 0.50 — 0.75 — 1.0 — 5 — 1.25 % in 0.25 % area.

Plate 3

Synoptic diagrams. Schmidt net. *Lower hemisphere. Isarithms for frequencies in 0.25 % diagra area. Cf.* also explanation of pl. 2.

D7. Orientations cell of detailed counting out, text-fig. 13.

D8. 242 relatively young lineations of areas 2—12.

D9. Geometric centers of relatively strong local absolute β-maxima (20 β or more in 1 % diagram area) of areas 2—12.

D10. Geometric centers of relatively weak local absolute β-maxima (less than 20 β in 1 % diagram area) of areas 2—12.

D11. Strikes of 720 small folds with overturning. Areas 3—12. Each point at the periphery records the strike of a particular small fold. Sense of overturning is clock-wise from each strike record. Strike rose in middle of diagram is based on a counting out of the points on the periphery with a counter cell of 3°.

D12. Fracture-cleavage with movement-striae. Areas 11—12. Broken lines = partial trace of planes containing cleavage-normals (dots) and movement-striae (rings). Crosses = normal of these planes. Isolated ringlets = small folds with fracture-cleavage.

D13. Area 9 (Jaurekaska). Concentration peaks of joint normals (rings with a dot in center and lineations (ring with a cross). Numerals indicate, for each of the joint normal maxima how many per cent of all joint normals that fall within 0.25 % of the diagram area. Stronges joint normal maximum shown in black, with white dot.

D14. Area 10 (Staddajokk). Concentration peaks of joint normals and lineations. Symbols a in D13.

D15. Area 12 (Balvatnet). Concentration peaks of joint normals and lineations. Symbols a in D13.

D16. All 2 490 β for adjacent *s*-surfaces in areas 1—3. Isarithms for 0.25 — 0.5 — 0.75 — 1 — 1.25 % in 0.25 % area.

D17. All 1 631 lineations of areas 1—3. Isarithms for 0.25 — 0.5 — 0.75 — 1 — 1.25 — 1.5 — 2 — 2.5 — 3 % in 0.25 % area.

D18. All 12 822 β of areas 4—6. Isarithms for 0.25 — 0.5 — 0.75 — 1 — 1.125 % in 0.25 % area.

D19. All 1 891 β for adjacent *s*-surfaces in areas 4—6. Isarithms for 0.25 — 0.5 — 0.75 — 1 — 1.25 — 1.5 % in 0.25 % area.

D20. All 1 953 lineations of areas 4—6. Isarithms for 0.25 — 0.5 — 0.75 — 1 — 1.5 — 2 — 2.5 — 3 % in 0.25 % area.

D21. All 11 763 β of areas 7—9. Isarithms for 0.25 — 0.5 — 0.75 — 1 — 1.25 — 1.5 — 1.75 — 1.875 % in 0.25 % area.

D22. All 1 772 β for adjacent *s*-surfaces in areas 7—9. Isarithms for 0.25 — 0.5 — 0.75 — 1 — 1.25 — 1.5 — 2 % in 0.25 % area.

D23. All 1972 lineations of areas 7—9. Isarithms for 0.25 — 0.5 — 1 — 1.5 — 2 — 2.5 — 3 — 3.5 — 4 — 4.5 — 6 — 7 % in 0.25 % area.

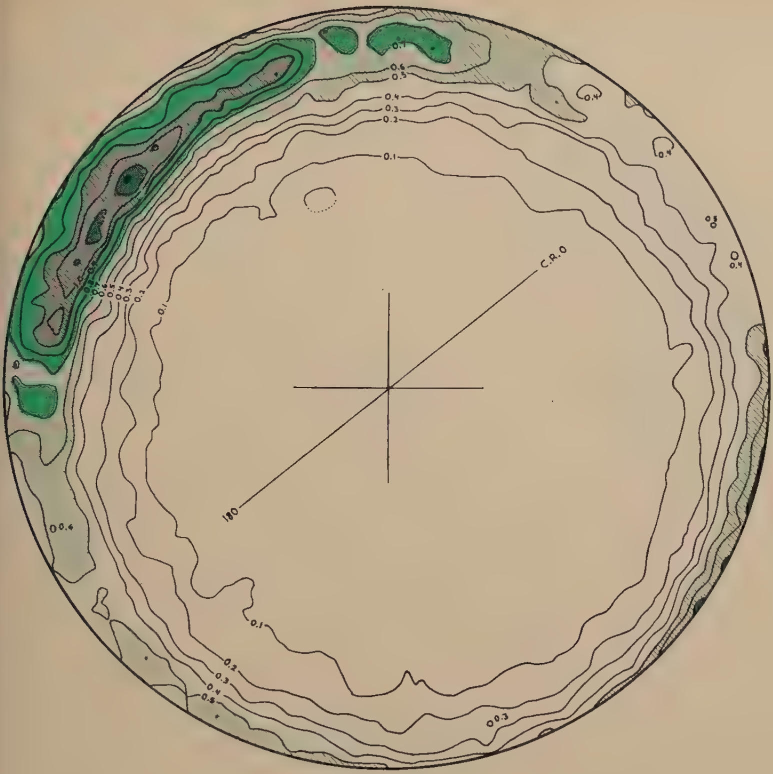
D24. All 11 494 β for areas 10—12. Isarithms for 0.25 — 0.50 — 0.75 — 1.0 — 1.125 — 1.2 % in 0.25 % area.

D25. All 1 655 β for adjacent *s*-surfaces in areas 10—12. Isarithms for 0.25 — 0.50 — 0.75 — 1.0 — 1.25 — 1.50 % in 0.25 % area.

D26. All 1 955 lineations of areas 10—12. Isarithms for 0.25 — 0.50 — 0.75 — 1.0 — 1.50 — 1.75 — 2.0 — 2.25 — 2.50 — 2.75 — 3.0 % in 0.25 % area.

D27. Orientations of 45 stretched pebbles in areas 8 and 10—12.

PL. 2:1


0.7
0.6
0.5
0.4
0.3
0.2
0.1
C.R.0
180
0.4
0.5
0.4
1.0
0.8
0.6
0.5
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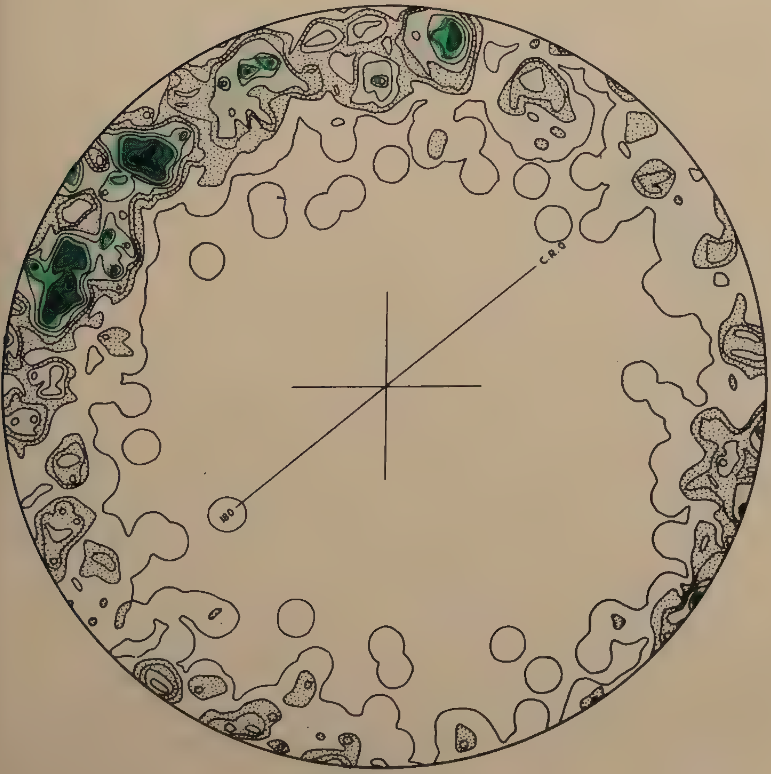
0.3

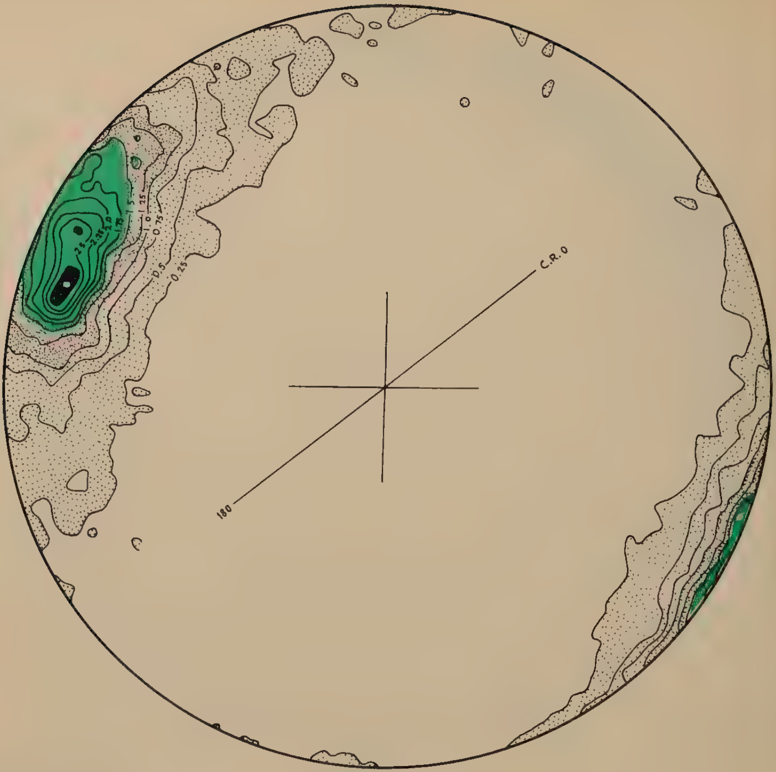
D 1


C.R.0
180

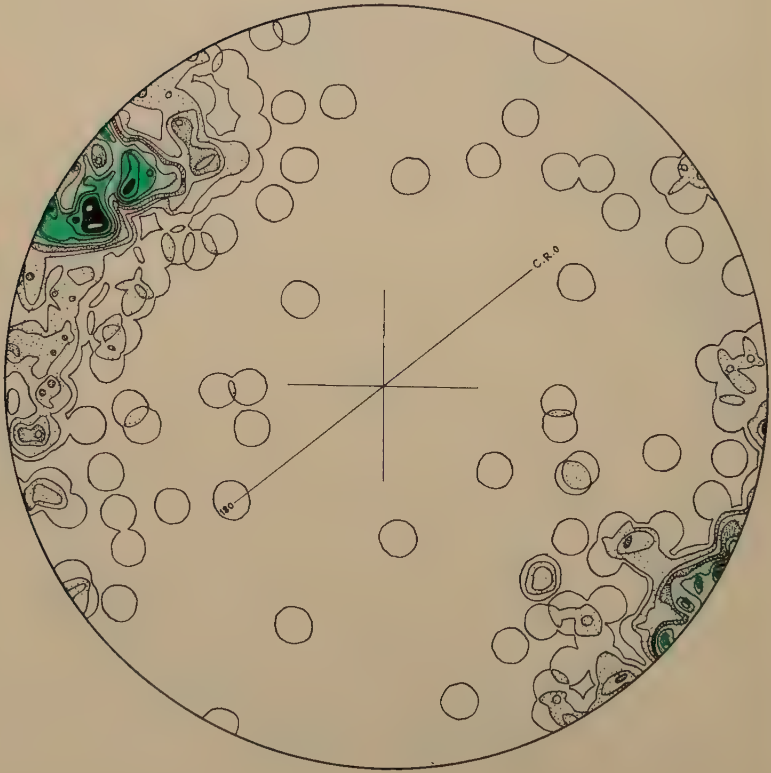
D 2

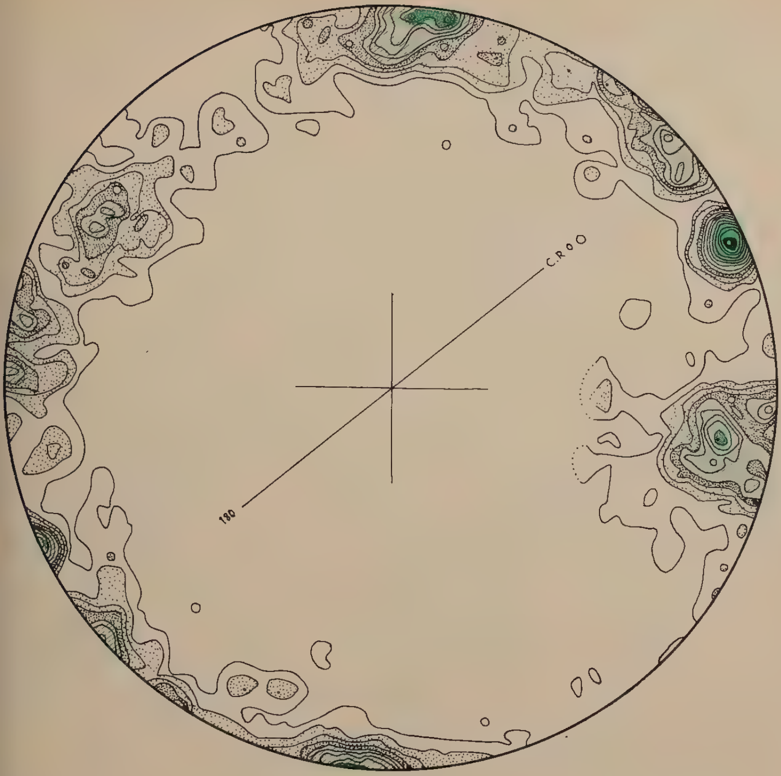
PL. 2:2

D 3



D 4





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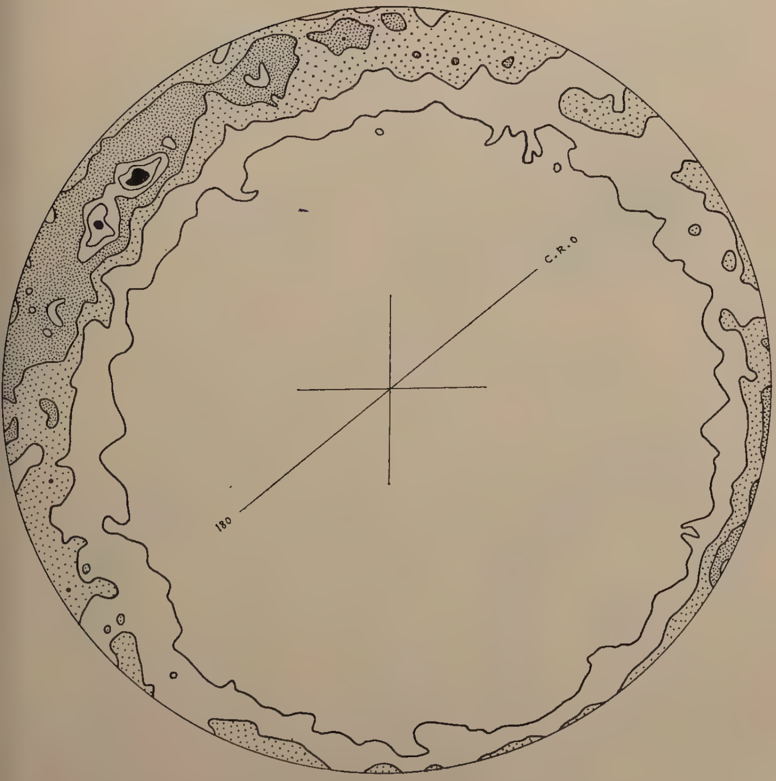
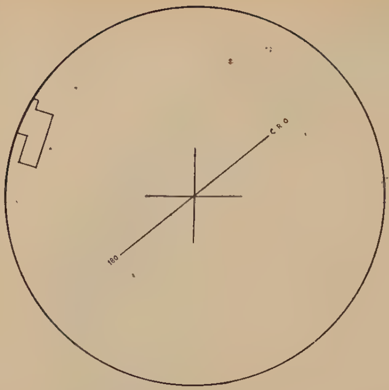
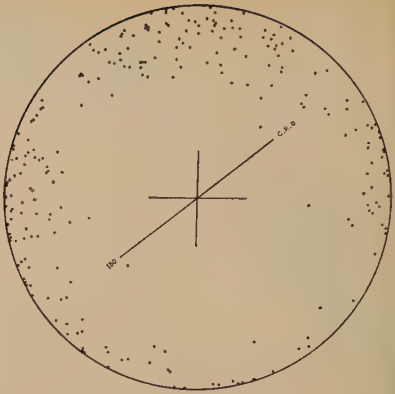


D 6

PL. 3:1

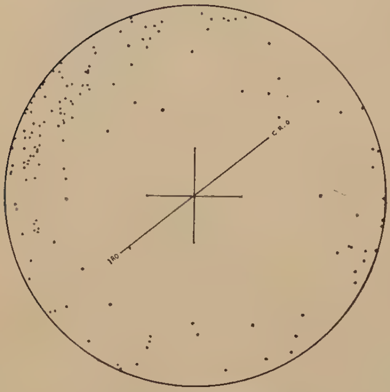
D 7

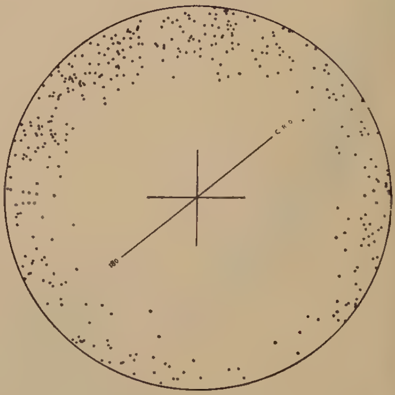




D

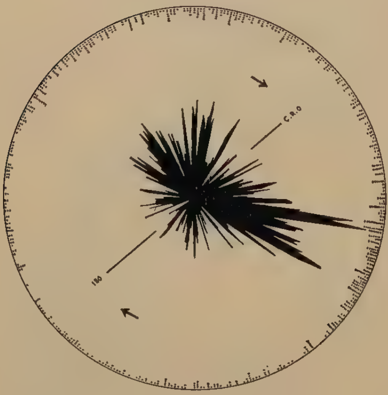
D 9

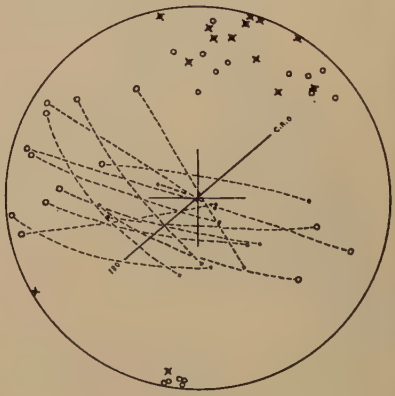




D

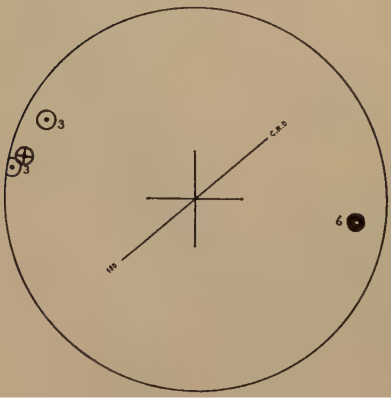
D 11

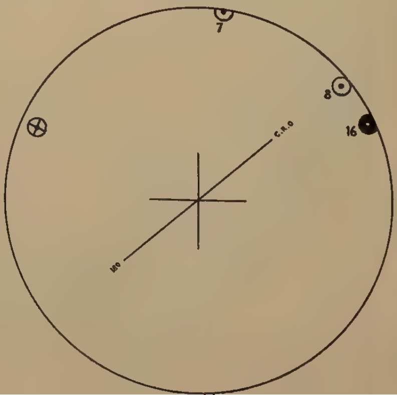




D

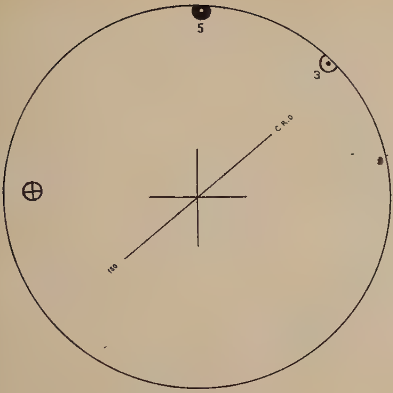
D 13





D

PL. 3:2



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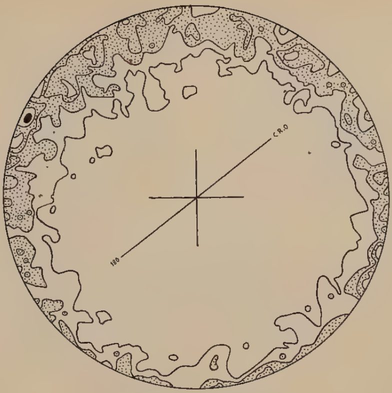
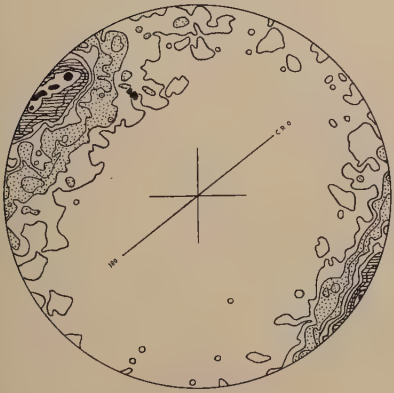


D 16



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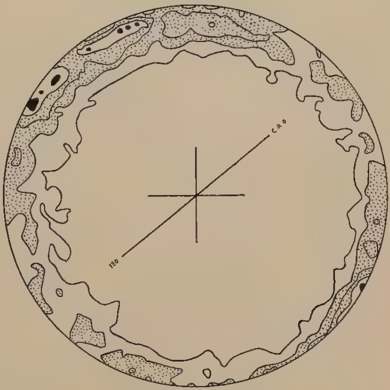
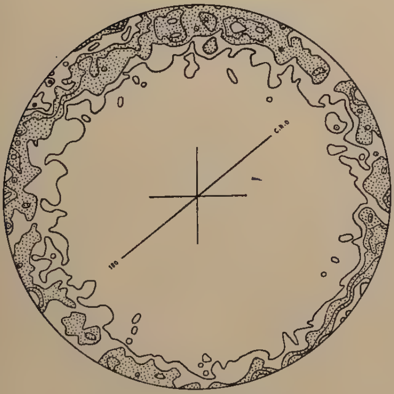


D 18



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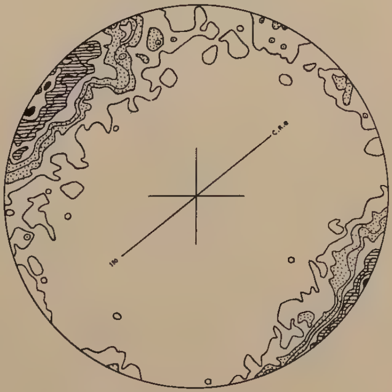
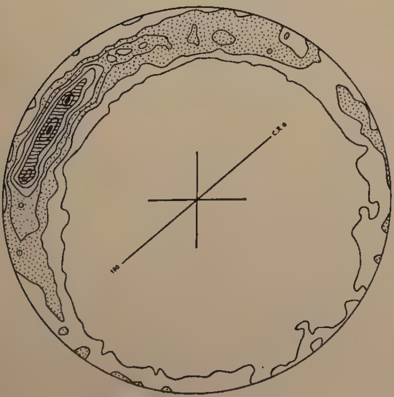


D 20



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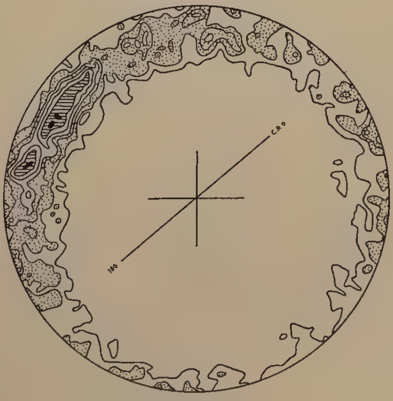
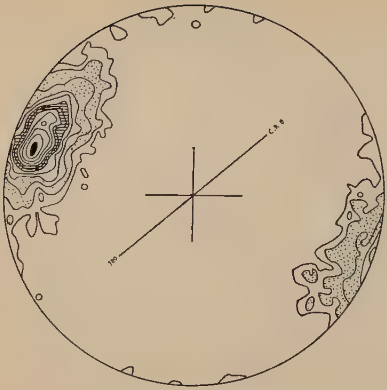
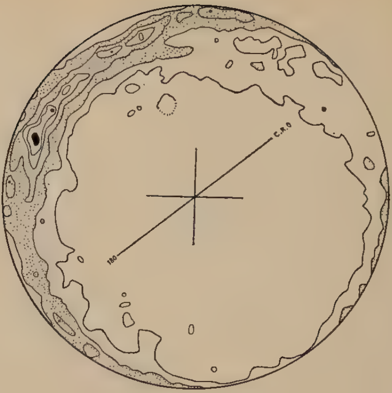


D 22

PL. 3:3



D 23



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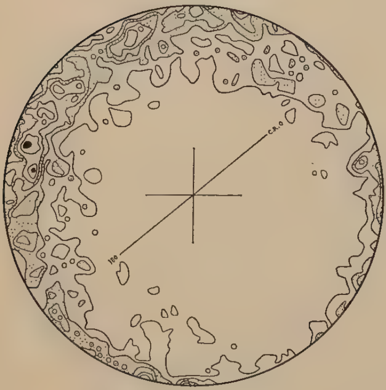

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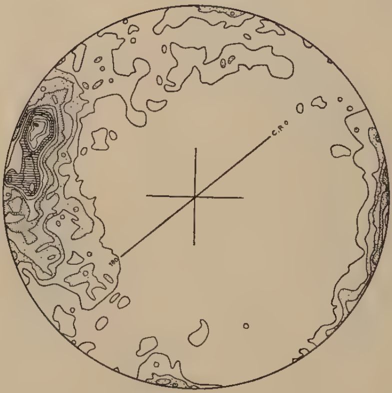
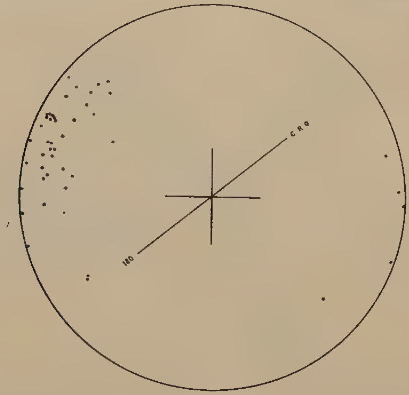


D 26



D 27

There is not any obvious constant relation between joints and lineations in the areas where they have been observed (*cf.* D 13—15, pl. 3).

There is a very close overlap between the joint normal maximum in C. R. 67—71 and the β maximum in C. R. 69 (D 6, pl. 2). Furthermore, there are two joint normal maxima approximately corresponding to the two β maxima in C. R. 130 and C. R. 136 (D 1, pl. 2).

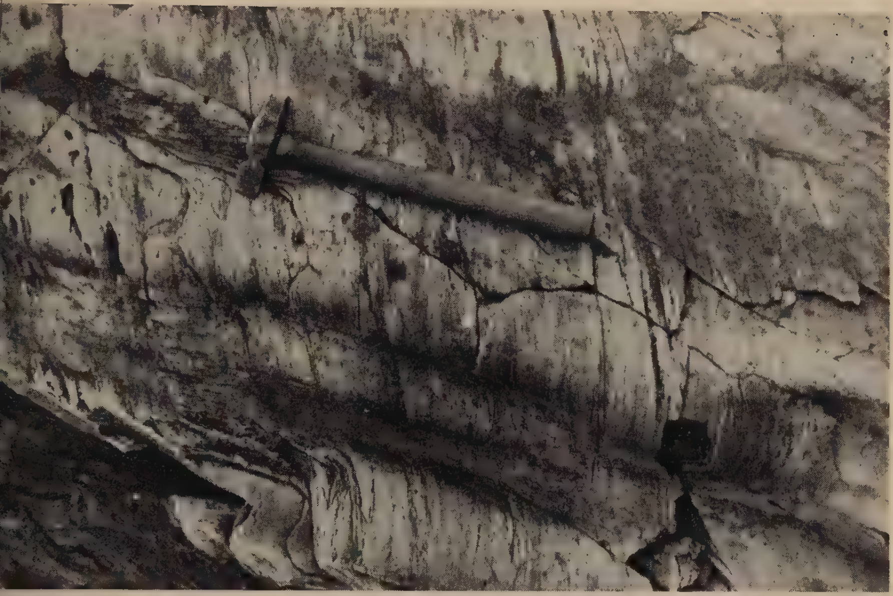
The joint orientations partly agree with a strike rose for joints compiled for the Sultitjelma area (that includes my area 11, Lommi) by Vogt (1927, p. 125). Vogt's strike readings are given to the nearest five degrees, so that the correlation cannot be exact. There are two great strike maxima, one in N 30° E (C. R. 160), which corresponds to my joint poles in C. R. 67—71, and one in N 60° W (C. R. 70), which does not have any apparent counterpart in my areas.

The joints must have arisen in response to stresses that came very late in the tectonic history of the areas. They cut straight across structures of all kinds and orientations, except for one notable example, in which joints have been visibly deformed to no small extent. This occurs in area 12 (Balvatnet), along the W and NW shore of Kvebilok. Particularly in the west, in the grey phyllites immediately beneath a gabbroic body, is the phenomenon very evident. Joints of nearly all orientations are deformed by small folds striking about N (C. R. 130). Local β-maxima have similar orientations, about N. The only joints that run straight through the deformed phyllites at Kvebilok belong to the joint pole maxima in C. R. 2 and C. R. 176. These joints are thus proved to constitute one of the youngest fabric regimes, if not the youngest, of my areas. They play a most important role in the topography of the area N of Balvatnet.

Constancy in Space of Tectonic Trends

The hypothetic model underlying the paper of Lindström 1956 was that several tectonic phases (or stages) had operated in the Scandinavian Caledonides and that these phases could be discerned by their different directions of main tectonic axes in certain areas (Lindström 1955). The axis of a given phase might according to the model be deflected from one area to the next, but the deflection might be so gradual that the axial trend of the first area could be identified in the other area provided that the areas were not too distant from one another. In later papers by me (1957, 1958 *a* & *b*) evidence was given for the hypothesis that the axes were not only identifiable, but that they tended to be identical from area to area. This can now be tested with more exact methods.

Even if the tectonic axes of a given phase have the same strikes over extensive areas, it is not necessary or likely that they are equally well developed everyhwere. They may be predominant in one area whereas they are sparsely represented or entirely absent in another. It is thus possible that, for instance two fold trends that diverge somewhat and that do not occur together were



g. 18. Lineations, striking in N75° E (C. R. 25), older than folds that strike in N5° E C. R. 135). Grey, largely phyllitic mica-schists with thin quartzitic beds, Balvatnet area (12), W of outlet of Balvatnet, N side of little bay due E of (629) on ordnance map. Looking S75° W.

ormed during different phases. The hypothesis of constancy in space of axial rend would thus not be disproved even if we were to find that the areas always differ as regards strike trends. Neither, of course, would it be proved; it ould remain an unwarranted postulate.

Adjacent areas have been brought together three and three. For each of the ur groups obtained in this way, synopses have been prepared for all β interctions of adjacent *s*-surfaces ("adjacent β") (D 16, D 19, D 22, D 25) and l lineations (D 17, D 20, D 23, D 26). Synoptic diagrams for all β interctions of every locality have been prepared for three of the groups of areas D 18, D 21, D 24), but not for the group consisting of areas 1—3, for a reason at is mentioned above (p. 27).

The strikes of maxima of 1 % and more in 0.25 % diagram area in these noptic diagrams are listed in table 2 and are shown graphically in text-fig. 6. The table and the figure show that certain strike trends, particularly for e strongest maxima, persist through the groups of areas. The best defined these trends consist of strikes about C. R. 69, C. R. 78, and C. R. 109 C. R. 109 = mainly β-maxima). There are several cases of maxima reapearing with identical strikes in adjacent groups of areas. However, there are so cases of strikes that appear to be deflexed a degree or so anti-clockwise as e proceeds southward from one group of areas to the next.

The evidence presented in table 2 and text-fig. 16 makes it plausible that ial strikes can be used for rough correlations of certain phases of deformaon within the sequence of areas investigated. It does, however, not prove that the strike of structures imposed by any given phase will tend to remain constant or nearly constant over a still greater distance.

A little support for the hypothesis of spatial constancy of tectonic trends is further given by a comparison of a diagram for area 2 (D 2, Lindström 1956, p. 565) with the diagram for local absolute β-maxima, D 2, pl. 2, of the present paper. The diagram for area 2 is a synopsis of local β concentrations of 8 % and more in 1 % diagram surface. Its maxima correspond rather neatly to the chief maxima in the diagram for all areas, in some cases with perfect coincidence. The circumstance that the pattern for the whole series of areas is a reproduction of the pattern found in an area near one of the ends of the series may imply that the patterns have the same general features from area to area.

There is thus a case for the hypothesis that structures created in the same phase have a certain degree of spatial constancy of orientation. More data will be needed, however.

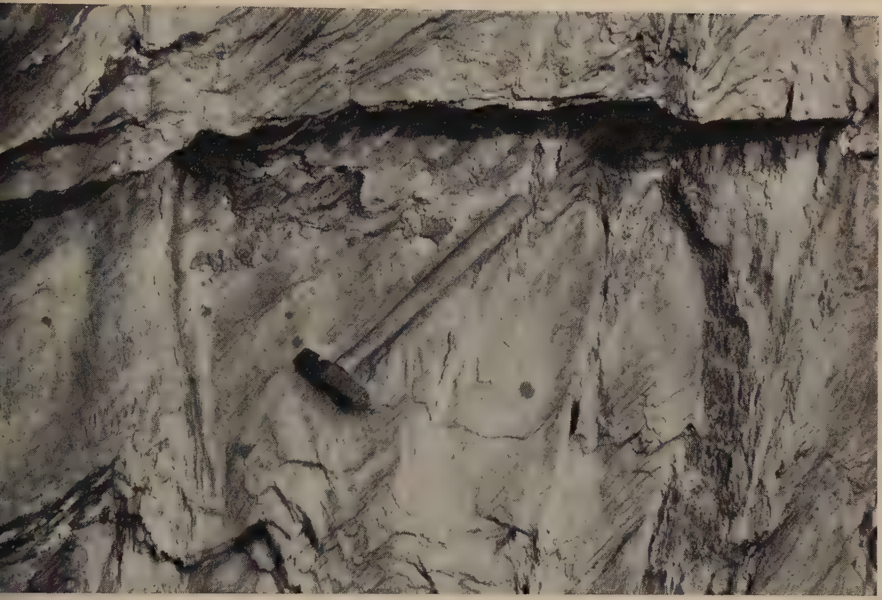
Phases of Deformation

When different phases of deformation in the northern Caledonides were first discerned by me, they were referred to by the directions of their main axial trends (the N couple, the NNE couple, the ENE couple, Lindström 1956, p. 561). This practise must be abandoned, if the trends of a given phase could change considerably from one place to another, or if different phases could have one and the same trend.

Accordingly, in Lindström 1957, the phases then discerned were given names that are fixed to certain deformation evidence at certain localities and thus have their objective applications, whatever turn the discussion about the phases may take. The typical evidence of the phases discerned in Lindström 1957 occurs in area 1 (Pålnoviken).

The name of the oldest of these phases, the Palnoluokta phase, is tied to lineations (inseparably related striations and folds) that strike N 47° W (C. R. 81) and occur in the lowest recognizable tectonic-stratigraphic unit of the area, viz., extremely fine-grained quartzo-feldspathic so-called hard-schists. Lineations of the same strike predominate in much of the hard-schists of the northernmost areas, 1—4. They contribute to the relatively old lineations of D 4, pl. 2, that possibly belong to the oldest fabric regimes of the whole series of areas (*cf.* above, p. 32).

A further deformation phase that has been regarded as younger than the Palnoluokta phase is the Trappsteget phase (*cf.* Lindström 1957, pp. 16, 18, 23—24). Its typical evidence that is found in the Pålnoviken area consists of a big overturned fold, the axis of which strikes N 64° E (C. R. 12). This strike has been regarded as B = *b* of the phase, and structures with axes at right angles to this have been regarded as B′ = *a*. The assumed B′ = *a* structures are much more common than structures with the typical strike C. R. 12, and



. 19. Lineations, striking about N46° W (C. R. 84), older than folds striking in N77° W R. 53) and N80° E (C. R. 30). Grey, soft phyllite, Lommi area (11), little stream through p" in "Vaknala*pp*a" (ordnance map). Note raindrops tending to spread along lineations. Looking E.

e also the structures that have been dated (*i.a.* by intersecting lineations) in ost of my previous investigations, whereas the evidence for the dating of the uctures striking in C. R. 12 is meagre. The observations that are now availa- e on the sense of overturning of small folds (D 11, pl. 3) make it seem un- ely that folds striking in C. R. 102 are simply B′ = *a* corresponding to B = *b* C. R. 12. There is not at present any evidence by which the two sets of uctures can be dated relative to one another.

The Raijkijokka phase (Lindström 1957) is regarded as younger than the appsteget phase. Its typical evidence is a twin set of slickensides in area 1 ålnoviken). The striae of these slickensides strike about N 5° W (C. R. 123) d normal to this direction. The phase is certainly very young, relatively eaking. With regard to the complications of the tectonic history of the areas at have become plausible, it is however no longer defensible to correlate the gely plastic deformations discussed in this paper with an instance of mainly ptural deformation.

If one is to trace tectonic events from area to area, it is essential to have a menclature for the phases of deformation. Yet further terms will have to be ned for such purposes. In the present context, where the areas are re- rded together, it will be superfluous to use local names for the phases dis- guished.

Comparison with the Total Diagram for the Scandinavian Caledonides

The two most prominent modes in my total diagram for the Scandinavian Caledonides (text-fig. 2) have the strikes C. R. 45 and C. R. 140. Neither of them has any exact counterpart in the total diagrams for my areas (*cf.* table 1). The diagram for local β-maxima (D 2, pl. 2) has minor frequency peaks in C. R. 46 and C. R. 139. There is a maximum for older lineations (D 4) in C. R. 44, and one for adjacent β in C. R. 141 (D 6). The best defined of the minor modes in text-fig. 2 offer a few more points of comparison. These modes occur at the strikes C. R. 3 (*cf.* D 4), C. R. 13 (*cf.* D 1), C. R. 22 (*cf.* D 4), C. R. 37 (*cf.* D 1, D 4, D 6), C. R. 61 (*cf.* D 1, D 2), C. R. 72 (*cf.* D 2), C. R. 86 (*cf.* D 1), C. R. 120 (*cf.* D 1, D 3, D 6), C. R. 133 (*cf.* D 2, D 6), and C. R. 150 (*cf.* D 6).

What may strike one most as regards this comparison is that it must be founded almost exclusively on β diagrams. The lineation strikes in my areas can hardly at all be compared with the strike rose, text-fig. 2. The chief lineation maximum, in C. R. 56, has the same strike as a rather deep mimimum i text-fig. 2. However, the same is true for the strongest β maximum, in C. R. 77.

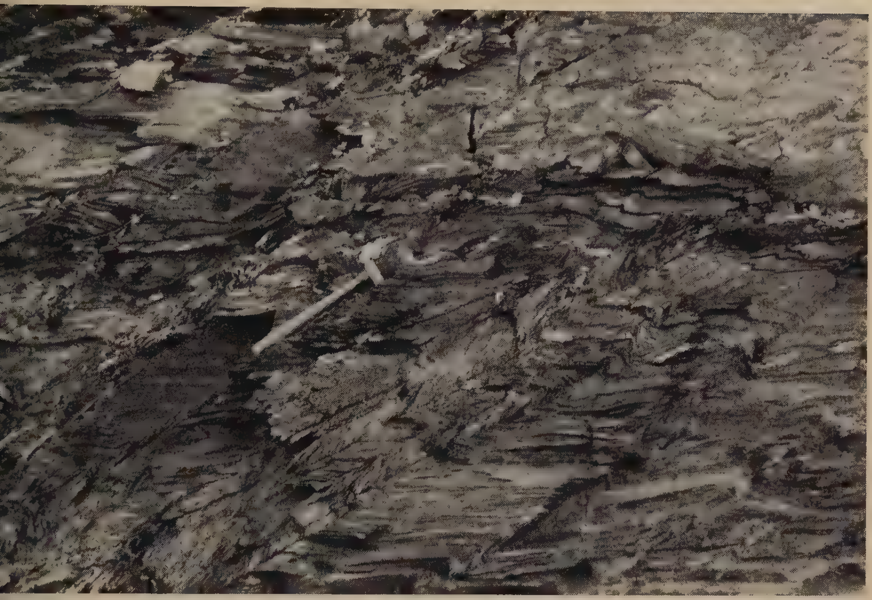
The comparison between the total synopses for my areas and the synopsis of published axial strikes in the whole of the Scandinavian Caledonides has revealed a number of similarities, but these are not so great that they definitely confirm the hypothesis that axial strikes in my areas may reappear over wider stretches. It must however be remembered that there adheres a far greater uncertainty to each of the data on which text-fig. 2 is founded than to the data collected in the field for the present investigation.

Comments and Conclusions

The tectonic data have been collected in 12 small areas, situated with rather even intervals along a 200 kilometers long segment of the Scandinavian Caledonides. The orientations of about 600 *s*-surfaces and 600 lineations have been recorded in each area. Synopses have been prepared for each area (not reproduced here), for every three areas, and for all the areas together.

1. Certain generalized axial strike trends can be followed through the whole sequence of areas. Other axial strikes are repeated in adjacent groups of three areas (table 2, text-fig. 16, text p. 51). In general and particular, however, the patterns of preferred strikes for the different groups of areas show important points of disagreement, which may be expected according to any hypothesis that involves phases of deformation with different directions of main movement. This makes it impossible to regard features of the total synopses as representative for particular areas.

2. The isarithms in the diagrams are based on a counting out with 0.25 % as the counter cell. The precision is thus greater than usual. However, an experiment in more detailed counting out (text-fig. 13, text p. 35) has shown



g. 20. Fracture-cleavage in phyllitic mica-schists. Balvatnet area (12), N shore of little lake (593) below Balvatnet Dam. Looking N.

t the patterns are still very generalized in the diagrams to be referred to ow.

. It is possible that lineations striking in C. R. 76—81 (D 4, pl. 2) are the est Caledonian deformation traces in my areas (p. 32). They occur largely he northernmost areas, 1—4, and include the typical evidence of the Paluokta phase (p. 52) of Lindström 1957. They are probably not older than nbrian, for they are penetrative in hard-schists that are a most extensive nponent near the base of a sheet of overthrust rocks resting on fossiliferous ver Cambrian (Kulling 1953). These lineations were probably formed allel to a tectonic transport (p. 37).

. Other relatively old lineations (D 4, pl. 2) have strikes about C. R. 67— (p. 30). These are parallel to a transport direction (conglomerate stretch- p. 37—38, D 27, pl. 3). They are not older than Ordovician, for they ur in fossiliferous Ordovician strata in area 11. Old lineations show a rather le correlation with β-maxima (text-figs. 6, 7, text p. 29).

The chief maximum for lineations (D 3, pl. 2) has the strike C. R. 56. probably younger than the lineations in points 3 and 4 (pp. 30—31, 32). probably transport-parallel (text-fig. 4, D 27, pl. 3, text p. 37—38). It is older than Ordovician, for in area 8 it is penetrative in fossiliferous rocks are Ordovician or younger. It shows a high degree of correlation with l β-maxima (text-fig. 10). These β-maxima concentrate about C. R. 53— D 2, pl. 2). They are mainly strong and indicate B-tectonites (pp. 28—29, D 9, pl. 3).

6. One of the two main concentrations of local β-maxima (D 2, pl. 2) wa dealt with under the previous point. The other has the strike C. R. 82, and i probably younger than the previous (p. 32). It shows a moderate correlatio with weak lineation fabrics of the same strike (text-fig. 11). Its relation to mai movement is unknown.

7. Local β-maxima (D 2, pl. 2) about C. R. 103—105 are possibly younge than the maxima of point 6 (p. 33). They show but feeble correlation wit lineations of the same strike (text-figs. 11, 12) that partly are relatively youn (text-figs. 8, 9). They are normal to the strongest set of boudinage crack (text-fig. 15, text p. 45). If they are syngenetic with the boudinage, they ar normal to a direction of greatest compression. The boudinage is proved (text fig. 14) to be younger than lineations about C. R. 55 (*cf.* point 5). Compar with point 9, below.

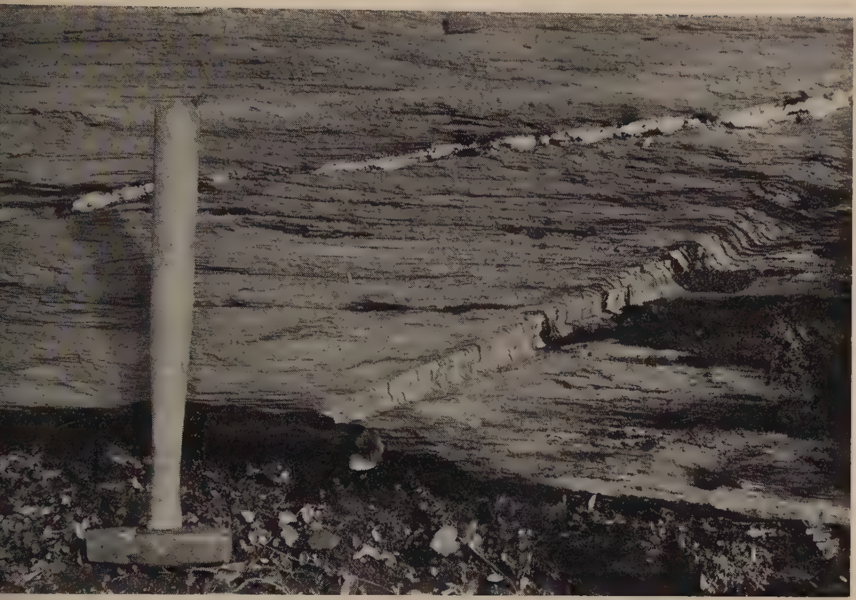
8. Local β-maxima striking in C. R. 139 probably tend to be younger tha the local β-maxima dealt with under point 6, and may possibly be younge than those under point 7 (D 2, pl. 2, D 9—D 10, pl. 3, text p. 33). These β maxima are not correlated with lineations in general (text-figs. 10—12). The could perhaps correspond to the small overturned folds about C. R. 322 (D 11 pl. 3, text p. 39), thus having been formed during a mainly easterly movemen (toward C. R. 52). They correspond in orientation to one of the most important strike maxima for the Scandinavian Caledonides as a whole, in C. R 140 (text-fig. 2, text p. 54).

9. Individual β intersections that tend to strike about C. R. 109 (D 1, pl. 2 may largely be younger than the local β-maxima of point 8, which strike abou C. R. 139 (p. 33). It is possible that the fabric regimes dealt with under poin 7 are not distinct from the present group. All the groups of areas have concentrations about C. R. 109 (text-fig. 16, table 2, text p. 51).

10. The strongest maximum for individual β intersections (D 1, pl. 2) ha the strike C. R. 77. It is certainly younger than the main lineation maximu dealt with under point 5 (*cf.* p. 31) and is distinct from the concentration o local β-maxima about C. R. 82 that is discussed under point 6. It is possibl younger than the β-intersections about C. R. 109 of point 9 (*cf.* p. 34). I occurs rather constantly in the different groups of areas (table 2, text-fig. 16

11. A concentration of β for adjacent *s*-surfaces (D 6, pl. 2) has the strik C. R. 69 and is regarded as mainly younger than the β about C. R. 77 discussed under point 10 (p. 34). It coincides with a group of joint norma (table 1, D 5, pl. 2, text p. 50). It is almost normal to an important set o boudinage cracks in C. R. 158 (text-fig. 15, text p. 45). It is sub-parallel t small folds that strike in C. R. 70 and are overturned toward SW (C. R. 160 (D 11, pl. 3, text p. 39).

12. The following fabric regimes cannot as yet be interpreted as relate to other structures: *overturned small folds* (D 11, pl. 3) in C. R. 51 (transpo toward C. R. 141) and C. R. 275 (transport toward C. R. 5) (p. 3 *boudinage cracks* in C. R. 115 (text-fig. 15, text p. 45), *joints* with norma in C. R. 15, C. R. 42, C. R. 48—52, C. R. 132—138, and C. R. 176—2. Th



21. Fracture-cleavage in soft phyllite. Lommi area (11), little stream through "pp" 'aknala*pp*a" (ordnance map), about 200 meters upstream from shore of Lomivatnet. Looking N30° E.

nentioned group of joints is very young, for it is undeformed at a locality ea 12 where other joints are deformed by structures striking in C. R. 130 C. R. 170 (my only case of deformed joints, *cf.* p. 50).

. Different sets of folds are overturned toward NW (D 11, pl. 3). One anding instance of this was in Lindström 1958 *a* (p. 44 & text-fig. 10) an elaborate explanation that must now be discarded, since every detail d in the deformation plane can be explained by a simple theory developed oeppener (1957). Slip planes have been rotated so as to become fracture- age that is nearly normal to an overriding pressure from SE. Outsqueeze es formed where two sets of slip planes were rotated together. A quartzite has been folded (bent) with the axial planes parallel to the cleavage. ar structures have been found in other places and are associated with a hrusting movement toward NW.

. As a summary of points 3—11 emerges a partly hypothetical picture of ement directions, rotated from phase to phase. If one is to assume the possible amounts of rotation of main direction of movement from phase ase as the most likely, one will further find that after having swung in ense over an arc that may be rather wide, the direction of main move- must have swung back in the opposite sense over an at least equally arc, only in order to finish by swinging in the first sense again. The or less probable or possible but certainly incomplete succession of move- directions is C. R. 76—81 (point 3) — C. R. 67—69 (point 4) — . 56 (point 5) — ? — (C. R. 172?, *cf.* point 6) — C. R. 13—15? (point

All β D 1		Local β — maxima D 2		Lineations D 3		Older lineations D 4		Adjacent β D 6		Joint poles D 5	
C. R.	%	C. R.	%	C. R.	%	C. R.	poles	C. R.	%	C. R.	%
1	0,5									2	1,75
				5	0,25	4	3	8	0,50		
12	0,5										
16	0,6									15	3,50
						20	3	25	0,50		
		34	1,25			30	5	33	0,75		
37	0,7					37	4	36	0,75		
		41	1,25							42	1,75
		46	1,50			44	4				
										48	2,25
50	1,0	53	2,25					53	1,0	52	1,75
		57	2.25	56	3,0	55	4				
61	1,1	61	2,25								
				65	2,25						
67	1,1	68	1.75			67	10			67	1,50
						69	10	69	1,25		
		73	1,75							71	1,50
77	1,2	77	1,50			76	9				
				80	1.50	81	8	80	1,25		
		82	2,25	83	1,50						
85	1,1										
		89	1,50			90	5	88	1,0		
		101	1,50			98	3				
		104	1,75	103	0,50						
109	0,9	109	1,75					107	1,0		
119	0,7			121	0.25			122	0,75		
130	0,7	128	1,50	130	0,25			130	0,75		
		133	1,25					134	0,75	132	2,50
136	0.7	139	1,75					141	0,75	138	2,50
				148	0,25			149	0,75		
				153	0,25						
156	0,5			156	0,25						
159	0,5										
		166	1,25					164	0,50		
170	0,5										
										176	2,0

Table 1. C. R. strikes of concentration peaks in the main synoptic diagrams.

Areas 1–3				Areas 4–6						Areas 7—9						Areas 10—12					
Adj. β D16		Lin. D17		All. β D18		Adj. β D19		Lin. D20		All. β D21		Adj. β D22		Lin. D23		All. β D24		Adj. β D25		Lin. D26	
C R.	%	C.R.	%	C.R.	%	C.R.	%	C.R.	%	C.R.	%	C.R.	%	C.R.	%	C.R.	%	C.R.	%	C.R.	%
						8	1 0														
																				16	1,0
												19	1,0								
												23	1,0					24	1,0		
																		28	1,0		
												34	1,0							32	1,25
										39	1,0							37	1,0		
						41	1,0														
												41	1,25							42	2,25
																		45	1,0		
		49	1,25																		
										49	1,75	**51**	2,0					**48**	1,50	51	2,0
55	1,0	54	1,25			54	1,0	53	1,50					**55**	7 0			**56**	1,50		
						60	1,0														
																58	1,25				
64	1,25																				
														65	4 50			65	1, 25	**64**	3,0
		67	3,0					**67**	3,0	**66**	1,875	**67**	2,0								
		71	3,0	**69**	1,125	**70**	1,50					**70**	2,0			**69**	1,25	68	1, 25		
				73	1,125																
																				74	1,25
78	1,0	**76**	3, 0	**79**	1,125	**78**	1,50	**76**	3,0	**78**	1,875					76	1,125	77	1, 25		
		82	3, 0			85	1,25	84	2,50									83	1, 25		
92	1,0			**93**	1,125	95	1,25	93	2,0												
										99	1,0					97	1,0				
				105	1,125			106	1,0	104	1,0	106	1,0								
107	1,0			**108**	1,125	107	1, 25					109	1,0			109	1,125	107	1, 25		
				111	1,125					111	1,0	112	1,0					112	1, 25		
																		118	1, 0		
						122	1,0														
																		125	1, 0		
						132	1,0					130	1,0					130	1, 0		
				135	1,0							134	1,0								
						142	1,0														
																		143	1, 0		
163	1,0																				
																		176	1, 0		
																		178	1, 0		

Table 2. C. R. strikes of concentration peaks in the diagrams for groups of areas. Strongets maxima indicated by bold-faced figures.

7, *cf.* point 9) — C. R. 49 (point 8) — C. R. 19 (point 9) — C. R. 167 (point 10) — C. R. 159 (point 11). In general, the intensity of deformation was reduced from phase to phase. The oldest discerned phase is probably not older than Cambrian. The youngest deformations are not necessarily Caledonian, or even Paleozoic.

15. Part of the evidence by which the phases are dated relative to one another is far from being conclusive. Since many will doubt the very existence of deformation phases that differed in direction of main tectonic movement, it is suitable to end by stating the case as briefly as possible. *Throughout the areas, lineations that are known to be relatively old differ constantly as regards orientation from lineations that certainly are younger (text-fig. 5). Throughout the areas (text-fig. 16) different kinds of fabric have divergent modes for axial strikes that cannot most easily be explained as due to one and the same plan of movement. The chief modes for β (D 1, D 6, pl. 2) cannot be correlated with the chief mode for lineations (D 3, pl. 2). The strongest mode for old lineations (D 4, pl. 2) does not coincide with the mode for lineations in general. The chief mode for boudinage (text-fig. 15) does not have any obvious relation to the chief mode for lineations. The strongest modes for joints (D 5, pl. 2) cannot be correlated either with β or with lineations.*

Literature Review

The following sample of contemporary opinions on divergent phases of deformation in western and central Europe is necessarily incomplete and will omit several of the most important papers. My main purpose is to show that representative points of view may be rather opposed to one another.

In a comprehensive paper on fabric studies in the eastern Alps, Karl (1954, pp. 150—151) sums up the observations of different authors as follows. It appears, according to Karl, "dass die verschiedenen alpidischen Teilformungsakte gleiche B-Achsenrichtungen prägten". Further, he finds that "nachgewiesen alpidische Formungen mit B-Achsenplänen ENE und WNW, und WNW, EW und ENE geologisch zeitlich einander sehr nahe rücken, teilweise sogar sich zeitlich überlagern". "Der Kreuzungswinkel der B-Achsenrichtungen zeigt eine gleichbleibende Streuung zwischen 15 und 30°. Nach den bisherigen Beobachtungen scheint eine Abhängigkeit dieser Winkelgrösse von der Höhe der Teilbeweglichkeit im Material zu bestehen."

If one is confronted with divergent trends of fold axes, as in the areas reviewed by Karl, one must refer to the orientations of fabric elements with great precision, or confine oneself to discussing the most obvious general features. However, Karl refers to the strikes as EW, ENE, NE, etc., or sometimes to the nearest ten or five degrees. His conclusions, important though they are, are therefore best regarded as statements of opinion.

For Rheinisches Schiefergebirge, Hoeppener (1955) and others conclude that practically all fabric orientations can be ascribed to phases of compression th essentially the same direction from the Devonian and into Tertiary times, . folds striking about N 60° E, fracture-cleavage, cross-joints, diagonal joints, d sinistral wrench-faults striking about N—S.

In other areas with Variscan tectonics (Fichtelgebirge, see Hofmann & chter 1959;Cornwall, see Wilson 1951), there is evidence of phases of de- mation with different directions, although it seems to be uncertain whether each case the different directions belong to the same orogeny.

In the Caledonides, Scottish areas have so far been most attractive to fabric earch. Alwyn Williams has studied the tectonics of the richly fossiliferous dovician and Silurian sediments of the Girvan area (1959). His results, that supported by a very great material of data, are that there were at least e phases of deformation, five of which were Caledonian. The sequence of ledonian phases led to overfolding, thrusting, and ultimately wrench-fault- . The phases may partly have overlapped in time. However, the general suc- sion of maximum stresses inferred by Williams has the strikes 1. N 10— ° W (C. R. 140—120), 2. N 35° W (C. R. 115), 3. N 70° W (C. R. 80), NE—SW (C. R. 15), and 5. N 20° W (C. R. 130). The C. R. figures are ded by me.

Fabric studies have become an essential tool for geologists working in the tamorphic terrains of the Scottish Highlands. A rather big area in the central ghlands has been studied by McIntyre (1951) and is, according to him, entially homoaxial. This is borne out strikingly by his diagram fig. 3, p. 5; lineations plunges cluster about 38° in S 57° E (C. R. 91) (however, each eation plot represents the mean of measurements at a particular locality. ch mean plots are likely be misleading, unless they are supplemented by a dering of all the data. Wide-spread but non-penetrative trends of struc- es may be obscured). Other areas in the Highlands show free and strong es of folding, with divergent and frequently very steep dips of limbs and s of folds. Detailed interpretations cannot be based on single areas, for ly structures may have been reoriented, and younger structures may depend pre-existing fabrics for their orientations. A paper by Clifford, Fleuty, Ram- , Sutton & Watson (1957) contains several instances of rocks refolded about erently oriented axes. King & Rast (1955) describe folds strikting NE and V in the Dalradian, but conclude that they were formed penecontempo- eously. For an area with Dalradian schists, Weiss & McIntyre (1957) con- de that NW-plunging folds were formed before folds striking about NE. a discussion that ensued between King & Rast and Weiss & McIntyre 59), this question of age-relationships of the folds played a subordinate t, and King & Rast appear to accept that Weiss & McIntyre's conclusions his respect may be correct for the area discussed by them. Whitten (1959) ls two directions of folding in an area investigated by him. Each trend ac- ding to him occurs in an essentially homoaxial sub-area. The folds were ned as one trend in a single deformation, but one of the sub-areas later ame rotated so that its fold trend came to diverge from the original. Whit- s conclusions are based on about 85 fold axes (figs. 8 B + 9 B + 11 B) and about 130 axial planes (figs. 8 A + 9 A + 11 A = fig. 10) in an area o more than 15 × 20 kilometers. The great-circles of axial plane poles (figs. 8 A 9 A) are dependent for their definition on but relatively few sub-vertical planes Nonetheless, Whitten's conclusion may be sound, and is certainly of grea theoretical importance.

Johnson (1957) has studied less steeply inclined tectonites in the southern part of the Moine thrust outcrop. He infers that lineations striking SE (about C. R. 105) in the Moine schists of the eastern parts of his area are the oldest fabric. In the western parts, near the Moine thrust, he has a first set of folds plunging in S 85° E (C. R. 65) and a second set in about N 15° E (C. R. 165) (Johnson 1957, fig. 4, p. 250). The first set may be parallel and the second set about normal to a direction of main movement. The two sets may have been formed penecontemporaneously, or the first set may be the oldest.

In the Scandinavian Caledonides, several authors have found that divergent axial trends may be explained by assuming different phases of deformation; others have ascribed the different trends to essentially one and the same orogenic process. These opinions were briefly reviewed in Lindström 1958 *b*. Lately, a paper by Rutland (1959) has appeared that deals witht an area about 75 kilometers WSW of my southernmost area (12, Balvatnet). Rutland's area is in the intensely folded central strip of the northern Caledonides of Scandinavia. Steep axial plunges are fairly common. There are two discernible main phases of folding, the first with axes striking ENE—WSW, and the second with a N—S axis. The structures belonging to the second fold episode are partly dependent for their orientations on structures formed by the first phase

The above review will show that there is considerable disagreement on the question whether different trends of tectonic axes are due to different deformation phases in the same orogeny. The opinions on this general question may depend on the attitudes or the methods of the investigators, but probably mos of all on specialization on terrains with different tectonic styles. It may be argued that there is not any general question: different orogenic tracts or different tectonic levels have behaved differently, that is all. However, one may doubt that this will prove to be the ultimate answer, for literature on the Caledonides supplies more and more instances of divergent fold trends that are most easily interpreted as due to different phases of deformation. The key area will be the more or less peripheral strips, where traces of early deformation may have survived, where the orientations of structures may lagerly have been preserved, and where tectonic and stratigraphic dating can be combined.

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Cormophyte Spore Classification

An Outline Based on the Apertures (Tremata)

By

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Systems for spore classification are generally based on several spore characters. he "NPC-system" outlined below, is based on one feature only, viz. the ertures (tremata), their number (N), position (P), and character (C).

Chiefly according to the number of the apertures the following classes can established ("classification N", cf. Column N, Tab. 1—7):

N 0. Atreme spores: without aperture(s).
N 1. Monotreme (1-treme) spores: with one aperture.
N 2. Ditreme (2-treme) spores: with two apertures.
N 3. Tritreme (3-treme) spores: with three apertures.
N 4. Tetratreme (4-treme) spores: with four apertures.
N 5. Pentatreme (5-treme) spores: with five apertures.
N 6. Hexatreme (6-treme) spores: with six apertures.
N 7. Polytreme (∞-treme) spores: with more than six apertures.
N 8. Anomotreme spores: with irregular or irregularly placed apertures (the spores in N 1—7 are nomotreme, i. e. provided with regular apertures).

Pleotreme spores have more than one aperture. Spores with four to many nally (monozonally or pleozonally) distributed apertures may be referred to stephanotreme (monozono-stephanotreme or pleozono-stephanotreme; the latter there are four or more than four apertures in each zone). N. B.: pore" here and in the following means pollen grain or spore or both according the context.

A more detailed classification can be made if, besides number, the character ape etc.) of the apertures is known. The following classes may be distinguished classification C"; cf. column C, Tab. 1—7):

C 0. Character unknown (ignote).
C 1. Monolept, dilept etc. ("tenuitatiferous") spores: with one or several leptomata (Gr. leptoma, plur. leptomata; from leptos, thin), i. e. thinwalled areas which may be engaged in forming an opening in connection with the normal exit of substance from the inner part of the spores.

C 2. Trichotomocolpate spores: with one (or exceptionally two) three-slit (three-armed) colpus (colpi).

C 3. Colpate (atomocolpate) spores: with one or several unbranched colpi.

C 4. Porate spores: with one or several pori.

C 5. Colporate (colp-orate) spores: with apertures consisting of a distal (or lateral-marginal) colpoid part and a proximal (or central) part known as an os (gen. oris, plur. ora). Colporate spores are with but few exceptions pleotreme. They form a morphologically heterogeneous group in need of revision.

C 6. Pororate (por-orate) spores: with apertures consisting of a distal, poroid part and a proximal part (os). Pororate spores are practically always pleotreme.

A more definite classification can be made if, besides number and character, the exact position of the apertures is known. The following position classes may be distinguished ("classification P"; cf. column P, Tab. 1—7):

P 0. Position unknown (ignote).

P 1. Catatreme spores: 1-treme spores with the centre of the aperture at the proximal pole.

P 2. Anacatatreme spores: 2-treme spores with one aperture with its centre at the distal and the other with its centre at the proximal pole.

P 3. Anatreme spores: 1-treme spores with the centre of the aperture at the distal pole.

P 4. Zonotreme (monozonotreme) spores: usually pleotreme spores with the centres of the apertures situated at the middle line of a zone coinciding with or parallel to the equatorial belt. — N. B. Zonocolpate spores are either orthocolpate (central line of the zone cutting the colpi at right angles) or loxocolpate (colpi converging in pairs), rarely clinocolpate (longest axis of the colpi coincident with the middle line of the zone).

P 5. Pleozonotreme (2-zonotreme, 3-zonotreme etc.) spores: pleotreme spores with the centres of the apertures situated at the middle lines of two (or exceptionally more than two) mutually parallel zones.

P 6. Pantotreme spores: spores with the apertures more or less uniformly distributed over the spore surface.

There are many transitions between certain aperture types. Spores with colpoid apertures may be classified as colpate, spores with colporoidate apertures as colporate etc.

Zonotreme spores with angular amb (ambit, ambitus) are either goniotreme (Gr. gonia, corner; syn. angulaperturate), i. e. the centres of the apertures are situated at the angles (cf. *Agastachys odorata* in Erdtman, Pollen Morphology and Plant Taxonomy. I. Angiosperms, Fig. 203 C, p. 348) or pleurotreme (Gr. pleura, side; syn. planaperturate), i. e. the centres of the apertures are ıt halfway between the angles (cf. *Ceiba pallida*, ibid., Fig. 33 A, p. 77). er zonotreme spores are ptychotreme (Gr. ptyx, gen. ptychos, a fold; syn. aperturate), i. e., their apertures are more or less deeply sunken (cf. *Gunnera oidea*, ibid., Fig. 118 C, p. 200). If the aperture margins and the adjoining s of the sporoderm are flaccid some ptychotreme spores may become itreme upon swelling (in peritreme spores the amb is circular or nearly so). ersely some peritreme spores with flaccid sporoderm may become ptychone upon shrinking. Peritreme spores with rigid sporoderm will always remain treme (cf. *Franklandia fucifolia*, ibid., Fig. 201 C, p. 345).

lassification N is "linear". By combining it with classification P we get a odimensional", by combining all three we get a "threedimensional" ification, the NPC or number-position-character classification. The followkey is based on this classification and can be used for classification of any ividual) spores if the key characters (N, P, C) or one (N) or two (N and P and C) of them are known. — "I" means G. Erdtman, Pollen Morphology Plant Taxonomy. I. Angiosperms. (1952), "II" Pollen and Spore Morphol- and Plant Taxonomy. II. Gymnospermae, Pteridophyta, Bryophyta. 7).

NPC-key to Nomotreme Spores

here are 7 N-classes, 7 P-classes, and 7 C-classes, or in all 7 × 7 × 7 = 343 lgeonholes" to accommodate the spores in the threedimensional NPC-system. ytwo holes, marked with heavy figures in Tab. 1—7, take the great majority ne spores. About 110, marked with ordinary figures in the tables, take the of the spores. The remaining holes (marked with a dash) have no function. NPC-analyses, e. g., in connection with studies of the "trema spectrum" ırypalynous families (Euphorbiaceae, Olacaceae, Rubiaceae, Sterculiaceae, , of angiosperms in various countries, of certain ecological plant groups, e fossil spores from a special epoch, or of pollen grains encountered in aero-, tto- and copropalynological investigations etc., an elementary card-index 78 reference cards can be used, viz. 9 N-cards marked N 1—9, 20 P-cards ked 10, 11, 13, 20, 24, 30, 34, 40, 44, 46, 50, 54, 60, 64—66, 70, 74—76, 84 C-cards marked 100—106, 111—114, 131—134, 200—206, 243—245, 301, 303—306, 343—346, 400, 401, 403—406, 443—446, 464, 500, 501, —506, 543—546, 600, 601, 603—606, 643—646, 654, 663—666, 700, 701, —706, 743—746, 754, 763—766. For a detailed card index, where also exceptional spores can be recorded, about 187 reference cards are required -cards, 27 P-cards, and 151 C-cards; cf. Tab. 1—7).

nly the monotreme spores are NPC-classified in full detail below. The es in the extreme left hand column correspond to the pidgeonholes in the -squares Tab. 1—7. More important classes are marked by heavy figures. names of the C-classes are in spaced-out type; if there are synonyms the name which seems to be most appropriate is in spaced-out type.

Tab. 1

MONOTREME				→	**i**	**l**	**t**	**c**	**p**	**co**	**po**
				→	0	1	2	3	4	5	6
1	ignote	0	ignote	0	100	101	102	103	104	105	156
1	cata-	1	-lept	1	110	**111**	**112**	**113**	**114**		
1	anacata-	2	-trichotomocolpate	2	—	—	—	—	—	—	—
1	ana-	3	-colpate	3	130	**131**	**132**	**133**	**134**	—	—
1	zono-	4	-porate	4	140			143	144	145	146
1	2-zono-	5	-colporate	5	—	—	—	—	—	—	—
1	panto-	6	-pororate	6	160				164		
N	POSITION	P	CHARACTER	C	N P C						

N 1. MONOTREME SPORES (Tab. 1)

P 0. POSITION UNKNOWN

100 C 0. Monotreme (character unknown)
101 C 1. Monolept
102 C 2. Mono-trichotomocolpate
103 C 3. Monocolpate s. lat.
104 C 4. Monoporate s. lat.
105 C 5. Monocolporate s. lat.
106 C 6. Monoporate s. lat.

P 1. CATATREME SPORES

110 C 0. Catatreme (character unknown)

111 C 1. Catalept. — Morphotype: *Polytrichum gracile* (II, Fig. 23 B, p. 116).

112 C 2. Cata-trichotomocolpate (trilete). — Morphotype: *Cerat pteris siliquosa* (II, Fig. 89, p. 52).

113 C 3. Catacolpate (monolete). — Morphotype: *Athyrium fili femina* (II, Fig. 84, p. 49).

114 C 4. Cataporate. — Previously sometimes referred to as hilat Occasionally encountered, e. g., in *Annona squamosa* ar some other annonaceous (usually catalept?) species.

— (115) C 5. Catacolporate (not encountered)
— (116) C 6. Catapororate (not encountered)

(P 2. ANACATATREME SPORES; are not monotreme by defir tion.)

P 3. ANATREME SPORES

C 0. Anatreme (character unknown)
C 1. Analept. — Morphotype: *Pseudotsuga taxifolia* (II, Fig. 63, p. 40).
C 2. Ana-trichotomocolpate (trichotomocolpate s. str.). — Morphotype: *Acanthorhiza mocinni* (I, Fig. 177 C, p. 305).
C 3. Anacolpate. — Morphotype: *Lilium bulbiferum* (I, Fig. 139, p. 237).
C 4. Anaporate. — Morphotype: *Zea mays* (I, Fig. 114 B, p. 194).
135) C 5. Anacolporate (not encountered)
136) C 6. Anapororate (not encountered)

P 4. ZONOTREME SPORES

C 0. (character unknown)
141) C 1. Zonolept (not encountered)
142) C 2. Zono-trichotomocolpate (not encountered)
C 3. Zonocolpate (1-colpate s. str.)
C 4. Zonoporate (1-porate s. str.). — Cf. *Leiphaimos flavescens* (I, Fig. 109 A, p. 185).
C 5. Zonocolporate (1-colporate s. str.). — Cf. *Landolphia comorensis* var. *florida* (I, Fig. 16 C, p. 51).
C 6. Zonopororate (1-pororate s. str.)

P 5. DIZONOTREME SPORES (are not monotreme)

P 6. PANTOTREME SPORES

C 0. Pantotreme (character unknown)
161) C 1. Pantolept (of theoretical interest only)
162) C 2. Panto-trichotomocolpate (of theoretical interest only)
163) C 3. Pantocolpate (of theoretical interest only)
C 4. Pantoporate (of theoretical interest only)
165) C 5. Pantocolporate (of theoretical interest only)
166) C 6. Pantopororate (of theoretical interest only)

Tab. 2

DITREME				→	i	l	t	c	p	co	po
				→	0	1	2	3	4	5	6
2	ignote	0	ignote	0	200	201	202	203	204	205	206
2	cata-	1	-lept	1	—	—	—	—	—	—	—
2	anacata-	2	-trichotomocolpate	2	220	221	222	223	224		
2	ana-	3	-colpate	3	—	—	—	—	—	—	—
2	zono-	4	-porate	4	240	241		**243**	**244**	**245**	246
2	2-zono-	5	-colporate	5							
2	panto-	6	-pororate	6	260	261		263	264	265	266
N	POSITION	P	CHARACTER	C	N P C						

N 2. DITREME SPORES (Tab. 2); main subdivisions only

P 2. ANACATATREME SPORES

220 C 0. Anacatatreme (character unknown)
221 C 1. Anacatalept
222 C 2. Anacata-trichotomocolpate
223 C 3. Anacatacolpate
224 C 4. Anacataporate

P 4. ZONOTREME SPORES

240 C 0. Zonotreme (character unknown)
241 C 1. Zonolept
243 C 3. Zonocolpate (2-colpate s. str.). — Morphotype: *Hypecoum procumbens* (I, Fig. 180 B, p. 311).
C 3 a. Orthocolpate (cf. *Hypecoum procumbens*)
C 3 b. Loxocolpate
C 3 c. Clinocolpate (cf. *Tigridia pavonia*, I, p. 214).
244 C 4. Zonoporate (2-porate s. str.). — Morphotype: *Cecropi*
obtusa (I, Fig. 158, p. 274).
245 C 5. Zonocolporate (2-colporate s. str.). — Morphotype: *An*
isosciadium isosciadium (I, p. 443).
246 C 6. Zonopororate (2-pororate s. str.).

Tab. 3

TRITREME			→	i	l	t	c	p	co	po
			→	0	1	2	3	4	5	6
ignote	0	**ignote**	0	300	301		303	304	305	306
eata-	1	**-lept**	1	—	—	—	—	—	—	—
anacata-	2	**-trichotomocolpate**	2	—	—	—	—	—	—	—
ana-	3	**-colpate**	3	—	—	—	—	—	—	—
zono-	4	**-porate**	4	340	341	—	**343**	**344**	**345**	**346**
2-zono-	5	**-colporate**	5							
panto-	6	**-pororate**	6	360	361		363	364	365	366
POSITION	P	CHARACTER	C	N P C						

N 3. TRITREME SPORES (Tab. 3); main subdivisions only (for further details see under Monotreme spores, p. 68)

P 4. ZONOTREME SPORES

3 C 3. Zonocolpate (3-colpate s. str.). — Morphotype: *Biscutella auriculata* (I, Fig. 73 A, p. 134).

C 3 a. Orthocolpate (cf. *Biscutella auriculata*).

C 3 b. Clinocolpate (cf. *Sphenostemon balansae*, I, Fig. 18 A, p. 55).

4 C 4. Zonoporate (3-porate s.str.) — Morphotype: *Roëlla ciliata* (I, Fig. 43 B, p. 91).

5 C 5. Zonocolporate (3-colporate s. str.). — Morphotype: *Lathyrus vernus* (I, Fig. 135 D, p. 228).

6 C 6. Zonopororate (3-pororate s.str.). — Morphotype: *Betula tortuosa* (I, Fig. 30 B, p. 72).

Tab. 4

TETRATREME				→	i	l	t	c	p	co	po
				↳	0	1	2	3	4	5	6
4	ignote	0	ignote	0	400	401		403	404	405	406
4	cata-	1	-lept	1	—	—	—	—	—	—	—
4	anacata-	2	-trichotomocolpate	2	—	—	—	—	—	—	—
4	ana-	3	-colpate	3	—	—	—	—	—	—	—
4	zono-	4	-porate	4	440	441		**443**	**444**	**445**	**446**
4	2-zono-	5	-colporate	5	450	451		453	454	455	456
4	panto-	6	-pororate	6	460	461			**464**	465	466
N	POSITION	P	CHARACTER	C	N P C						

N 4. TETRATREME SPORES (Tab. 4); main subdivisions only

P 4. ZONOTREME SPORES

443 C 3. Zonocolpate (4-colpate s. str.). — Morphotype: *Desmostachys preussii* (I, Fig. 126 D, p. 212).

C 3 a. Orthocolpate (cf. *Desmostachys preussii*).

C 3 b. Loxocolpate (cf. *Myriophyllum spicatum*, I, Fig. 118 A, p. 200).

444 C 4. Zonoporate (4-porate s. str.). — Morphotype: *Harmandia mekongensis* (I, Fig. 172 F, p. 295).

445 C 5. Zonocolporate (4-colporate s. str.). — Morphotype: *Platonia insignis* (I, Fig. 116 D, p. 196).

C 5 a. Orthocolpate (cf. *Platonia insignis*).

C 5 b. Loxocolpate

446 C 6. Zonopororate (4-pororate s. str.).

P 6. PANTOTREME SPORES

464 C 4. Pantoporate (4-pantoporate).

Tab. 5

ENTATREME		→		**i**	**l**	**t**	**c**	**p**	**co**	**po**
			→	0	1	2	3	4	5	6
ignote	0	ignote	0	500	501		503	504	505	506
cata-	1	-lept	1	—	—	—	—	—	—	—
anacata-	2	-trichotomocolpate	2	—	—	—	—	—	—	—
ana-	3	-colpate	3	—	—	—	—	—	—	—
zono-	4	-porate	4	540	541		**543**	**544**	**545**	**546**
2-zono	5	-colporate	5							
panto-	6	-pororate	6	560				564	—	566
POSITION	P	CHARACTER	C	N P C						

N 5. PENTATREME SPORES (Tab. 5); main subdivisions only

P 4. ZONOTREME SPORES

C 3. Zonocolpate (5-colpate s. str.). — Morphotype: *Pterodiscus kellerianus* (Pedaliac.).

C 4. Zonoporate (5-porate s. str.).

C 5. Zonocolporate (5-colporate s. str.). — Morphotype: *Juliania adstringens* (I, Fig. 129, p. 216).

C 6. Zonopororate (5-pororate s. str.).

Tab. 6

HEXATREME				→	i	l	t	c	p	co	po
				→	0	1	2	3	4	5	6
6	ignote	0	ignote	0	600	601		603	604	605	606
6	cata-	1	-lept	1	—	—	—	—	—	—	—
6	anacata-	2	-trichotomocolpate	2	—	—	—	—	—	—	—
6	ana-	3	-colpate	3	—	—	—	—	—	—	—
6	zono-	4	-porate	4	640	641		**643**	**644**	**645**	**646**
6	2-zono-	5	-colporate	5	650	651		653	**654**	655	656
6	panto-	6	-pororate	6	660	661		**663**	**664**	**665**	**666**
N	POSITION	P	CHARACTER	C	N P C						

N 6. HEXATREME SPORES (Tab. 6); main subdivisions only

P 4. ZONOTREME SPORES

643 C 3. Zonocolpate (6-colpate s. str.). — Morphotype: *Catopheria chiapensis* (I, Fig. 130 C, p. 218).

644 C 4. Zonoporate (6-porate s. str.). — Morphotype: *Thelygonum cynocrambe* (I, Fig. 246, p. 429).

645 C 5. Zonocolporate (6-colporate s.str.). — Morphotype: *Neochamaelea* (*Cneorum*) *pulverulenta* (I, Fig. 60 B, p. 115).

646 C 6. Zonopororate (6-pororate s.str.). — 6-pororate grains occur, e. g., in *Pterocarya* spp.

P 5. DIZONOTREME SPORES

654 C 4. Dizonoporate (3 + 3). — Morphotype: *Anacolosa lutea* (I, Fig. 172 B, p. 295).

P 6. PANTOTREME SPORES

663 C 3. Pantocolpate (6-pantocolpate). — Morphotype: *Spergula arvensis* (I, Fig. 50 B, p. 102).

664 C 4. Pantoporate (6-pantoporate). — Morphotype: *Fumaria officinalis* (I, Fig. 180 D, p. 311).

665 C 5. Pantocolporate (6-pantocolporate)

666 C 6. Pantopororate (6-pantopororate)

Tab. 7

POLYTREME		→		i	l	t	c	p	co	po
			→	0	1	2	3	4	5	6
ignote	0	ignote	0	700	701		703	704	705	706
cata-	1	-lept	1	—	—	—	—	—	—	—
anacata-	2	-trichotomocolpate	2	—	—	—	—	—	—	—
ana-	3	-colpate	3	—	—	—	—	—	—	—
zono-	4	-porate	4	745	741		**743**	**744**	**745**	**746**
2-zono-	5	-colporate	5	750	751		753	**754**	755	756
panto-	6	-pororate	6	760	761		**763**	**764**	**765**	**766**
POSITION	P	CHARACTER	C	N P C						

N 7. POLYTREME SPORES (Tab. 7); main subdivisions only

P 4. ZONOTREME SPORES

C 3. Zonocolpate (polycolpate s. str.). — Morphotype: *Josephinia grandiflora* (I, Fig. 183 A, p. 316).

C 4. Zonoporate (polyporate s. str.)

C 5. Zonocolporate (polycolporate s. str.). — Morphotype: *Monnina oblongifolia* (I, Fig. 194, p. 332).

C 6. Zonopororate (polypororate s. str.).

P 5. DIZONOTREME SPORES

C 3. Dizonoporate ($\infty/2 + \infty/2$).

P 6. PANTOTREME SPORES

C 3. Pantocolpate (polypantocolpate). — Morphotype: *Echinocactus tabularis* (I, Fig. 41, p. 88).

C 4. Pantoporate (polypantoporate). — Morphotype: *Salsola tragus* (I, Fig. 54 B, p. 107).

C 5. Pantocolporate (polypantocolporate).

C 6. Pantopororate (polypantopororate). — Morphotype: *Juglans rupestris*.

ADDENDUM:

N 0. ATREME SPORES. — Morphotype: *Cinnamomum camphora* (I, Fig. 132, p. 222).

N 8. ANOMOTREME SPORES

Example: SPIROTREME SPORES. — Morphotype: *Eriocaulon septangulare* (I, Fig. 94 A, p. 163).

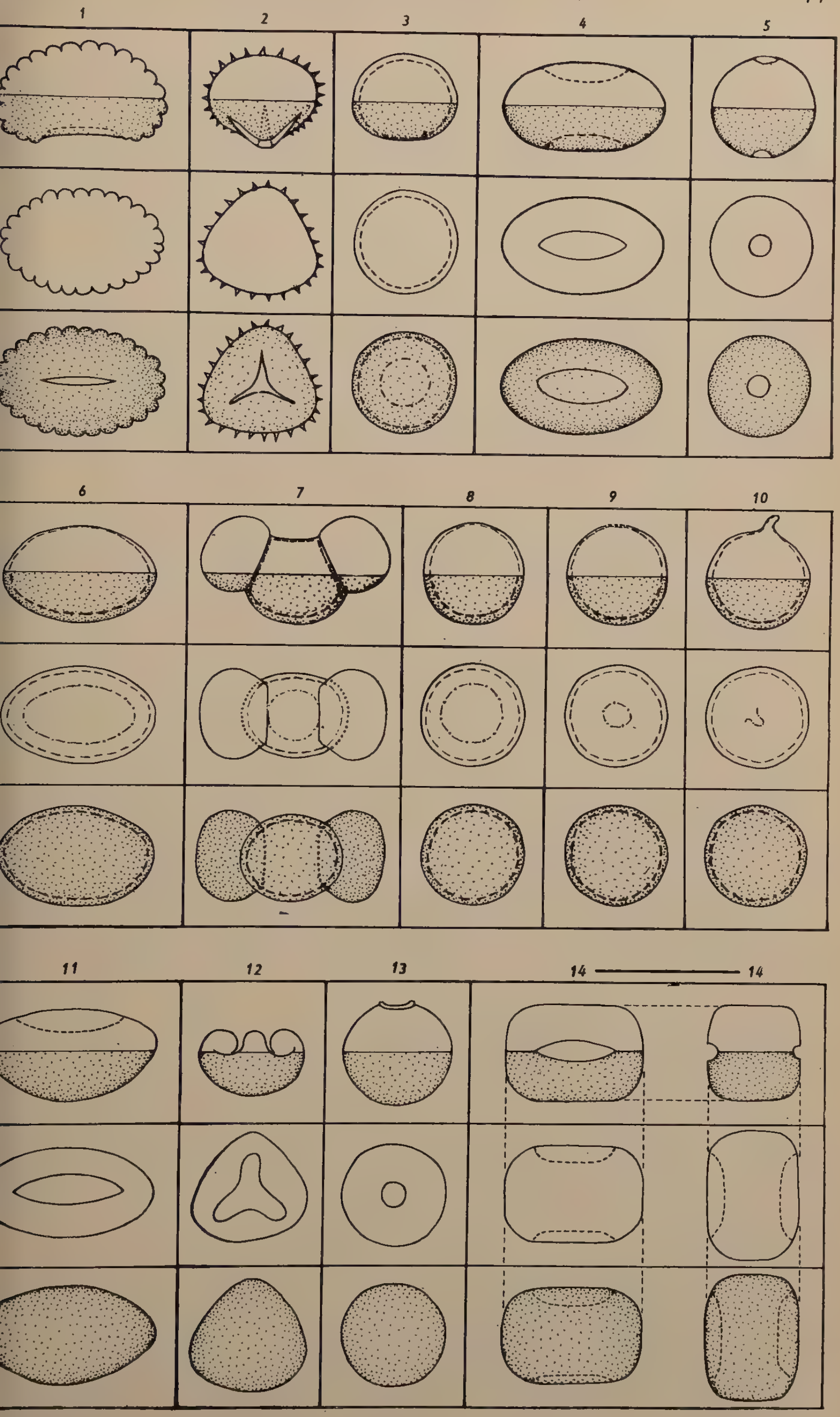
Figs. 1—25. NPC-classification (examples).

N-classification. — Monotreme: 1—3, 6—13. — Ditreme: 4, 5, 15. — Tritreme: 15, 17, 19, 20. — Tetratreme: 16. — Hexatreme: 18 (dizonotreme, 3+3). — Polytreme: 21—24. — Atreme, 25.

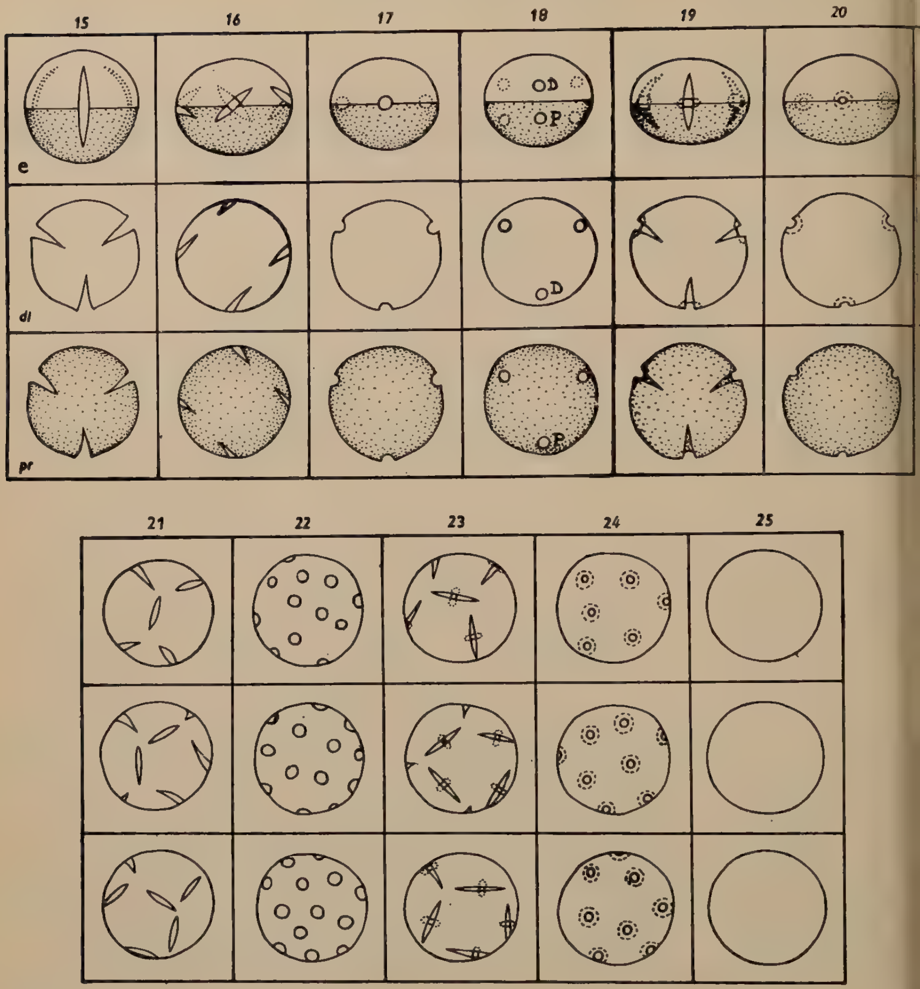
P-classification. — Catatreme: 1—3. — Anacatatreme: 4, 5. — Atreme: 18. — Pantotreme: 21—24.

C-classification. — Monolept: 3, 6—10. — Trichotomocolpate: 2 (referred to as 3-lete), 12. — Colpate: 1 (referred to as 1-lete), 4, 11, 14 (clinocolpate), 15 (orthocolpate), 16 (loxocolpate). — Porate: 5, 13, 17, 18, 22. — Colporate: 19, 23. — Pororate: 20, 24.

NPC
1 : 113, catacolpate (monolete).
2 : 112, cata-trichotomocolpate (trilete).
3 : 111, catalept.
4 : 223, anacatacolpate.
5 : 224, anacataporate.
6 : 131, analept, bilateral, non-saccate.
7 : 131, analept, bilateral, saccate.
8 : 131, analept, radiosymmetric, non-saccate.
9 : 131, analept, microlept.
10 : 131, analept, micro- and prolept.
11 : 133, anacolpate. — Syn.: sulcate, monocolpate p. p.
12 : 132, ana-trichotomocolpate (trichotomocolpate s. str.).
13 : 134, anaporate. — Syn.: ulcerate; monoporate p. p.
14 : 243, zonocolpate (2-colpate clinocolpate). — Syn.: 2-sulculate.



. 1—14.



Figs. 15—25.

15 : 343, zonocolpate (3-colpate orthocolpate).
16 : 443, zonocolpate (4-colpate loxocolpate). — Syn.: 4-rupate; pericolpate p. p.
17 : 344, zonoporate (3-porate).
18 : 654, dizonoporate (3 + 3).
19 : 345, zonocolporate (3-colporate).
20 : 346, zonopororate (3-pororate).
21 : 763, pantocolpate. — Syn.: rugate; pericolpate p. p.
22 : 764, pantoporate. — Syn.: polyforate; periporate.
23 : 765, pantocolporate. — Syn.: rugorate; pericolporate.
24 : 766, pantopororate. — Syn.: polyforaminorate; periporate.
25 : 000, atreme. — Syn.: inaperturate; non-aperturate; acolpate etc.

– – – – – approximate outline of leptoma.

–·–·–·– inner contour of exine in spores provided with leptoma.

e, equatorial view; di, distal face; pr, proximal face; D and P in Fig. 18, pore in dista
and proximal face respectively.

Middle and Upper Ordovician Strata at Lindegård in the Fågelsång District, Scania, S. Sweden

Preliminary Report

By

C. F. Glimberg

tract. A brief description is given of a boring through the Tretaspis series and the
ermost portion of the Chasmops series in the Fågelsång district. The examined por-
s of the Chasmops series agree with the corresponding strata in Bornholm. The
taspis strata which hitherto had been almost unknown in the area consist mainly of
mudstones and shales including black graptolitiferous layers. They exhibit remark-
similarities with the Moffat series in Scotland and the sequence from Brzezinki in
nd. The following subdivisions are distinguished (from below upwards): 1) Zone
retaspis granulata; 2) Zone of *Dicellograptus anceps;* 3) Practically unfossiliferous
dstones for which the term *Lindegård mudstone* is proposed.

Introduction

Jp to the present time the Tretaspis series has been one of the least known
uences in the Cambro-Silurian of Scania. Within the Fågelsång district,
ut 8 km E. of Lund, it is nowhere exposed. With the kind assistance of the
n Head of the Palaeontological Institute at Lund, Dr. J. E. Hede, a boring
ld be carried out in February 1949 the expenses of which were defrayed by
grant received from the Faculty of Natural Sciences and the Palae-
ological Institute of Lund University. The location of the boring (Fig. 1)
chosen with a view of obtaining as complete a section as possible. Ac-
ding to the geological guide to the Fågelsång area by Moberg (1910), the
rest locality, E 27, which is now longer accessible, was an exposure of the
trites shale. In the well of Lindegård farm which has a depth of more than
etres the zone of *Akidograptus acuminatus* is met with *in situ.* For this
rmation the author is indebted to Dr. Seth Stenestrôm. The Dalmanitina
es was entirely unknown within the region, and was supposed to be of in-
siderable thickness.

issures and similar features made the boring rather difficult, and upon
y levels considerable portions of the core were lost. — The dip of the
ta is 10°—15°.

Middle Ordovician Strata

he boring was continued for 6.87 m below the Tretaspis series. These layers
sist for the greatest part of black, usually easily split shales with brown
ak. As can be seen from the diagram corrosion surfaces occur in two hori-

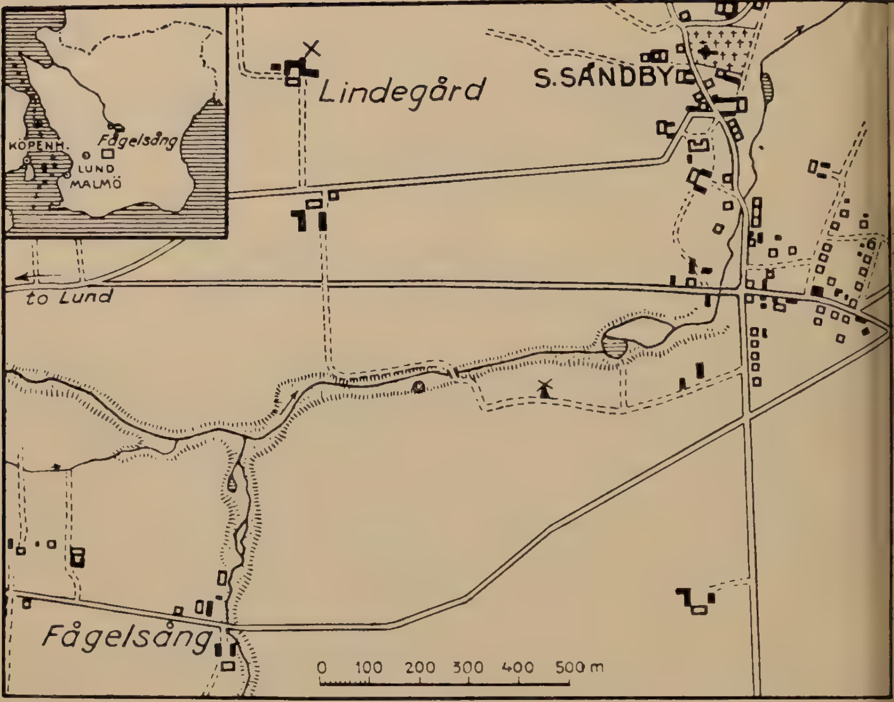


Fig. 1. The site of the Lindegård boring marked on a map from Hede (1951).

zons. Upon the upper of them (53.58 m) rests an about 6 cm thick layer o metabentonite. This is rich in mica, and contains some pyrites. A very thin dar layer of metabentonite occurs at 54.40 m, and at 55.80 m was found an abou 4 cm thick band of limestone with corroded upper surface and probably a almost completely washed-away layer of metabentonite. The strata exhibi fairly good agreement with the corresponding formations in Bornholm There exist great similarities also with regard to the fossil content. On this ac count it may appear suitable to apply Hadding's (1915) division into zones i spite of the fact that later investigations have shown the guide fossils *Diplo graptus molestus* Thorslund (= Hadding's *Climacograptus rugosus* Tullberg and *Amplexograptus vasae* (Tullberg) to have a greater vertical range tha had previously been assumed (Hede 1951, Ragnar Nilsson 1953, Jaanusson an Strachan 1954).

1. The “Zone of *Diplograptus molestus* Thorslund”

Below 57.25 m. Apart from the abundantly occurring guide fossil we fin *inter alia* *Climacograptus scharenbergi* Lapworth, *Lasiograptus* cf. *mar garitatus* (Lapworth), “*Obolus*” *celsus* Hadding, “*O.*” *rugosus* Hadding, an *Anatifopsis elongatus* Hadding. As supposed by M. Lindström already in 195 for palaeontological reasons the boring shows that the Sularp shale (earlie

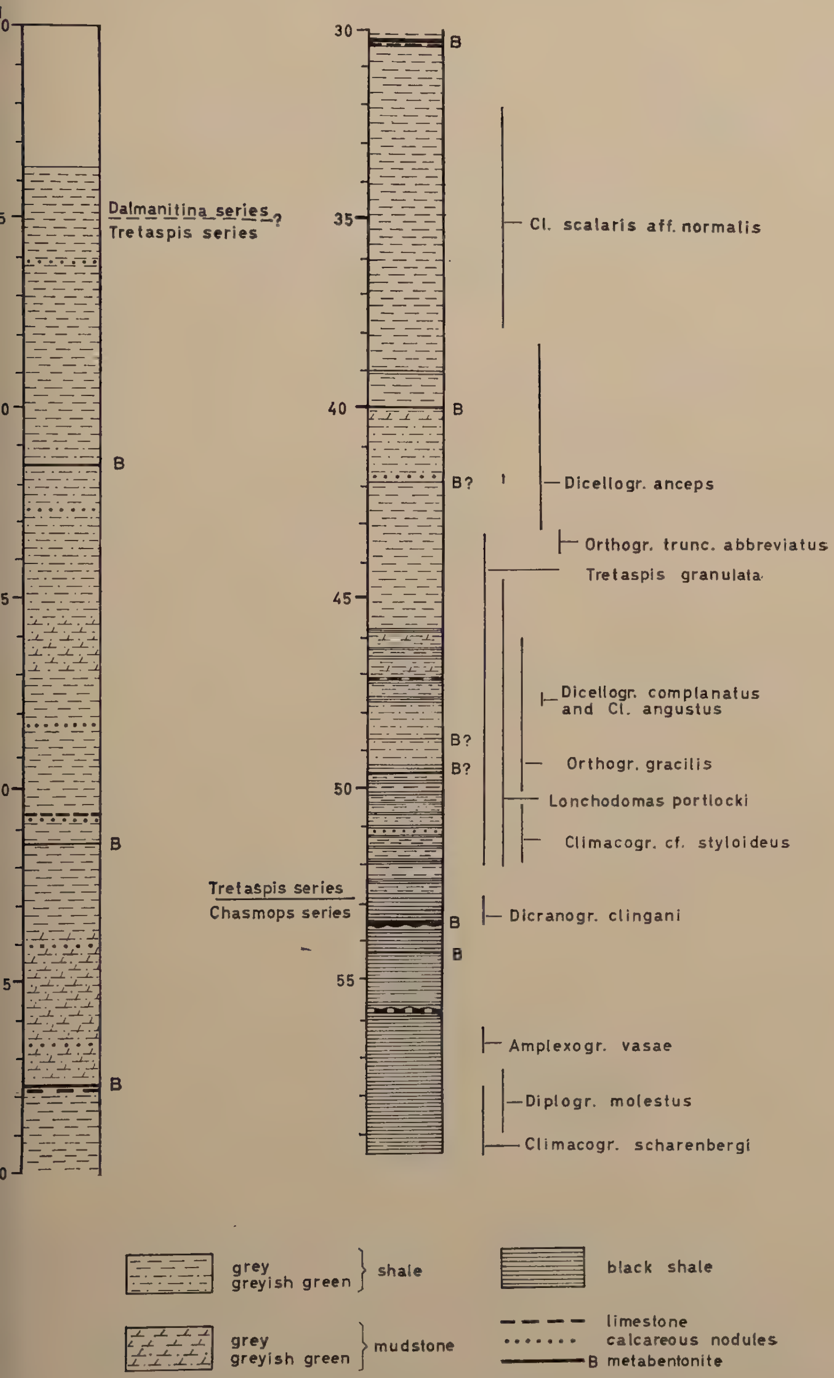


Fig. 2. Diagram of the Lindegård boring.

Correlations c

Great Britain	
Graptolitic succession	Moffat series (according to Lapworth 1878)
Zone of *Dicellogr. anceps*	C. 1.8 m greenish-grey, unfossiliferous shale, identical with the ty- pical beds of the "*Barren Mudstone*". C. 1.8 m alternating greenish unfossiliferous shales and dark soft fossiliferous mudstone and shale with *Dicellograptus anceps*.
Zone of *Dicellogr. complanatus*	C. 9 m grey and greenish mudstones without fossils — "*Barren Mudstone*". C. 3 m from the base a 2 inches thick seam of black shale with well preserved graptolites, e. g. *Dicellograptus complanatus*.
Zone of *Pleurogr. linearis*	Black graptolitic shales.

called Orthis shale) is not younger than the "zone with *Diplograptus molestus* It ought rather to fall within the "zone".

2. The "Zone of *Amplexograptus vasae* (Tullberg)"

57.25—55.80 m. As upon Bornholm the "zone" is rather poor in fossils. Tc gether with the guide fossil the following have been encountered: *Lasiograpt* cf. *margaritatus* (Lapworth), "*Obolus*" *celsus* Hadding, "*O.*" *rugosus* Haddin *Sericoidea restricta* (Hadding).

3. The Zone of *Dicranograptus clingani* Carruthers

55.80—52.85 m. The lowermost 2.22 m are with some doubt referred to th zone. The single graptolite encountered there is *Corynoides incurvus* Haddin There occur furthermore, together with the brachiopods mentioned for th preceding "zone", *Paterula* cf. *portlocki* (Geinitz), "*Lingula*" *magna* Haddin and *Anatifopsis elongatus* Hadding. Above the level of 53.58 m the guide foss occurs in abundance, and furthermore, amongst others, *Mesograptus compact* (Lapworth), *Orthograptus truncatus truncatus* (Lapworth), *Climacograpt* retaspis beds

Scania			Poland
General division	Lindegård Boring		Brzezinki (according to Kielan 1956)
ocephalus beds		C. 27 m almost unfossiliferous grey and greyish green shales and mudstones. — *Lindegård Mudstone.*	23 m completely unfossiliferous mudstones.
		C. 11 m grey and greenish shale and mudstone, upper part with *Climacograptus scalaris* aff. *normalis*, lower part with *Dicellograptus anceps*. — Zone of *Dicellograptus anceps*.	
of *Opsima-* *s latus* *'Niobe" lata*) *Dicellogr. com-* *tus*	Zone of *Tretaspis granulata*	C. 6 m grey and greyish green shale and mudstone with *Tretaspis granulata*. C. 2 m from the base a band of black shale, 10 cm thick, rich in well preserved graptolites, e. g. *Dicellograptus complanatus*.	32 m light trilobitic mudstones with *Tretaspis granulata. Staurocephalus clavifrons*, etc.
of *Pleurogr.* *is*		Black and grey shale with *Climacograptus* cf. *styloideus* and *Tretaspis granulata*.	25 m light-coloured mudstones with trilobitic beds, amongst others with *Tretaspis granulata*. Black graptolitic shales with *Climacograptus styloideus*.

atus Lapworth, *Corynoides incurvus* Hadding, *Hisingerella nitens* (Hi-
r), *H.* cf. *nana* (Hadding), *Paterula* cf. *portlocki* (Geinitz), "*Obolus*"
s Hadding, *Sericoidea restricta* (Hadding).

Upper Ordovician Strata

THE TRETASPIS SERIES

1. The Zone of *Tretaspis granulata* (Wahlenberg)

85—43.33 m. Two subdivisions can be distinguished:

52.85—49.65 m. Grey to almost black shales, rich particular in in-
ulate brachiopods and ostracods, but poor in both graptolites and trilobites.
subdivision probably corresponds to the graptolite zone with *Pleurograp-*
nearis.

49.65—43.33 m. Mixed trilobitic and graptolitic facies, separated from A
thin band of limestone. Alternation between pale or dark, often mottled
ish mudstones or shales, greenish grey sediments reminding of shell beds,
ure black graptolite shales. The latter show their best development be-
47.64 and 47.74 m, i.e. the zone proper with *Dicellograptus complanatus*.

The upper boundary of the zone with *Tretaspis granulata* is not petr graphically expressed, but has been drawn so as to coincide with the disa pearance of the guide fossil and with the incipient appearance of *Dicellogra tus anceps*.

Among the fossils are noticed: *Climacograptus* cf. *styloideus* Lapworth (A *Cl. augustus* (Perner) (B), *Orthograptus gracilis* (Roemer) (A and B), *truncatus abbreviatus* Elles and Wood (B), *Dicellograptus complanatus* La worth (B), *Lonchodomas portlocki* (Barrande) (A and B), *Trinodus tard* (Barrande) (B), *Sphaeragnostus* cf. *cingulatus* Olin (B), *Tretaspis granula* (Wahlenberg) (A and B), *Cyclopyge rediviva* (Barrande) (B), *Panderia meg lophthalma* Linnarsson (B), *Hisingerella nitens* (Hisinger) (A), *H.* cf. *nar* (Hadding) (A), *Paterula* cf. *bohemica* Barrande (A and B), *P.* cf. *portloc* (Geinitz) (A and B), *Sowerbyella quinquecostata* (M'Coy) (B), *Sericoide restricta* (Hadding) (A and B), *Resserella argentea* (Hisinger) (B), *Kinn kullea hofsteni* Henningsmoen (B), *K. thorslundi* Henningsmoen (A and B *Primitiella tenera* Linnarsson (A and B), *Lepidocoleus suecicus* Moberg (and B).

2. The Zone of *Dicellograptus anceps* (Nicholson)

4.33—c. 32 m. Preponderately greyish green, often mottled shales and mu stones with intercalations of grey shales. In the dark portions of the lower ha of the core *Dicellograptus anceps* (Nicholson) is found, in the upper half form of *Climacograptus* very similar to, but not identical with *Cl. scalaris no malis* (Lapworth). Nor is it identical with any of the forms described by Waer in 1948. The light-coloured portions contain only isolated small brachiopoc

3. The Lindegård Mudstone

C. 32—5 m. The sediments are still mostly greyish green, often mottl shales and mudstones with scattered thin layers of limestone and metabe tonite. The poor condition of the core prevented the fixation of the upp boundary. The paucity of fossils is evident. Only isolated small brachiopods an *Primitiella tenera* Linnarsson have been encountered. For this reason the auth has decided to designate this series of strata by the name of Lindegård mu stone.

4. Correlations

The Tretaspis layers in the borehole exhibit great similarities with the co ditions in Scotland (Lapworth, Davies, etc.) and Poland (Kielan). They mig be said to occupy a position intermediate between these two regions. The co ditions appear from the correlation table.

THE DALMANITINA SERIES

The occurrence of the Dalmanitina series has not been proved by the borin but has been established subsequently by digging on the spot.

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Grottorna i Lummelunda

En orientering

Av

LEANDER TELL

Abstract: The cave at Lummelunda, Gotland, is developed along an undergroun stream in Silurian reef limestone. The mouth of the cave is situated in a scarp nea the present coast line, above the Litorina strandline. The cavern system, consisting o open rooms and narrow channels, is known to an extent of more than 150 m from th mouth (Fig. 1).

Bakom den slottsliknande bruksherrgården vid Överstekvarn eller Lummelunds forna järnbruk omkr. 13 km norr om Visby öppnar sig i den äldr strandbrinken en vackert valvformig grotta, 6 m bred och 3 m hög. Grotta är omkr. 12 m lång och består av en låg vattenfylld och en högre torrlagd del Ständigt friskt vatten strömmar fram ur en bred spricka i grottans sydöstr hörn.

I Henr. Munthes grottutredning av år 1917[1] betecknas denna s. k. Kyt Janns källare som en kombinerad strand- och utlösningsgrotta, vari »mynn ett underjordiskt litet vattendrag eller en rikt flödande källa». Redan Linn är dock mera utförlig på denna punkt: »Strömmen vid Överste-Kvarn är där uti mycket underlig, att han, sedan han tagit sin begynnelse i Martebo träsk går därifrån vid pass 1/16 mil under jorden, under berg och dalar och äntlige kommer upp vid Överste-Kvarn, där landborgen emot västra sidan är avbruten, där han utlöper liksom utur ett litet valv av 2 famnars bredd och 1 famn höjd.»[2]

Grottan är ett typiskt karstfenomen i silurisk kalksten, och endast dess yttr del kan ha varit utsatt för marin erosion. Litorinahavets strandvallar ligga nedanför grottans mynning. Sannolikt ha de mjuka konturerna uppstått på samma sätt som raukarna, d. v. s. genom vittring och atmosfärisk erosion. Ett vidsträckt område ända från västra kanten av forna Martebo myr och ut till landborgen, d. v. s. på två kilometers avstånd, uppvisar de för ett karstlandska säregna företeelserna såsom slukhål, underjordiska vatten, doliner, grotto »fönster» (med håligheter kommunicerande sprickor), raukar, klapperstenbäddar m. m.

Detta förhållande har uppmärksammats av bl. a. G. Lundqvist, som i S. G. U beskrivning till vederbörande kartblad anmärker: »Vi ha här alltså ett motstycke till Sydeuropas karstområden.»[3] C. Chabot medger visserligen förekom

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[1] Henr. Munthe, Strandgrottor och närstående geologiska fenomen i Sverige, Naturskyddsu redning, Stockholm 1920.

[2] Carl von Linnés Gotländska Resa förrättad 1741, Stockholm 1957.

[3] G. Lundqvist, J. Ernhold Hede och N. Sundius, Beskrivning till kartbladen Visby och Lumm lunda (SGU, Ser. Aa, nr 183), Stockholm 1940.

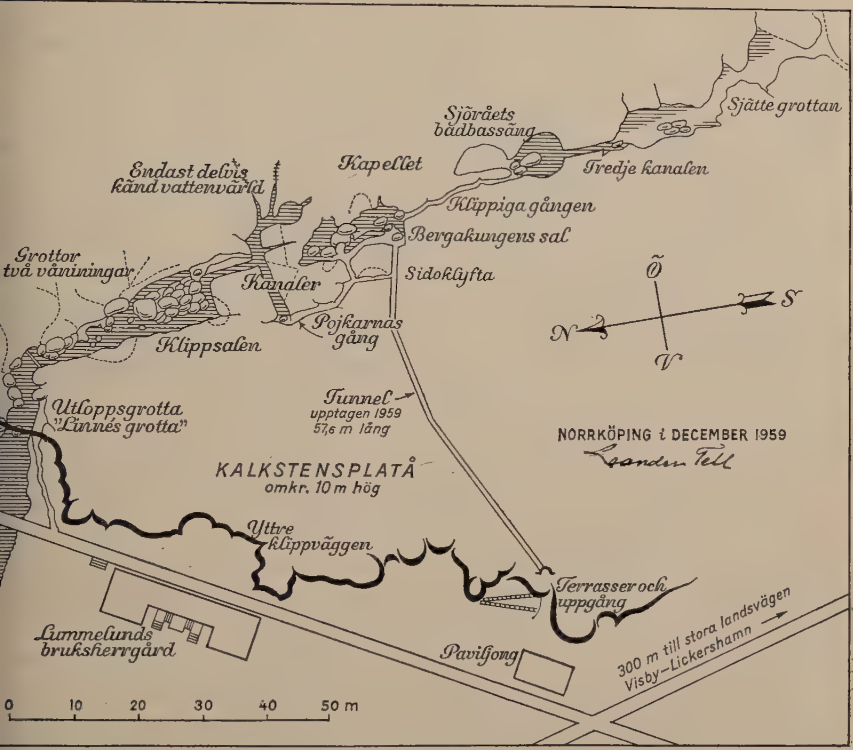

Fig. 1. Hittills upptäckta grottor vid Lummelunds bruk, Lummelunda, Gotland.

v enstaka karstfenomen men säger samtidigt (i övers.): »Vi äro här långt
de betydligt tjockare homogena kalklager som erfordras för att utveckla
arstområde.»[4] Hans landsman J. Corbel gör gällande (i övers.) »att ett
rjordiskt vattensystem förekommer endast längs Ancylushavets strand».[5]
t förefaller egendomligt, att den livliga verksamhet, som tidigt uppstod
Lummelunda nedre ström,[6] icke även lett till att närmare utforska vatt-
underjordiska lopp. Från år 1925 har förf. ägnat sig åt att tränga in såväl
röms från grottan som medströms från det 1 300 m avlägsna Stora Sluket
nmelundaåns övre synliga del. Utöver den 15 m söder om grottan befint-
stora »klippsalen», vilken tidigare beskrivits av Gislén-Brinck,[7] har man
da nppnått dels ett anslutande vidsträckt system av vattenfyllda gångar
märre grottor, dels en serie stora droppstensgrottor, av vilka flera äro ett
otal meter långa, över tio meter breda samt av varierande höjd mellan 2
m. Under, ovanpå och vid sidan av grottorna finnas ytterligare håligheter,

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habot, La naissance d'un karst: l'ile de Gotland dans la mer baltique (Annales de Géo-
L. II nr 289), 1943.
rbel, Les phénomènes karstiques en Suède (Geografiska annaler nr 3—4), 1952.
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laströmmen (Lunds Univers. årsskrift), Lund 1948.

och mellan dem vindla krypgångar, gallerier och andra passager, ofta i form av smala och djupa naturliga kanaler. Omfattningen av det nu kartlagda underjordiska landskapet framgår av vidfogade skiss, vari de vid slukhålen upptäckta övre grottorna dock icke medtagits.

Förf. har på annat ställe[8] utförligt skildrat sina tidigare expeditioner, av vilka många verkställts i groddräkt eller på gummiflotte, samt omtalat sina medhjälpare och de djärva visbygymnasister, vilka år 1954 upptäckte den trånga och besvärliga krypgång, som leder in till de nya grottorna. Här må endast erinras om att redan den yttre sedan gammalt kända grottan uppvisar en rad intressanta erosionsfenomen.

Grottpartiet är under- och överlagrat av den vanliga hårt bankade Visby övre märgelsten. Bottenhällen är sålunda jämn och slät, och det plana översta »taket» skymtar i en lång fyra meter hög spricka mellan den bergvägg, vari det höga yttre valvet bildats, och ett inre parti, vars nedre kant höjer sig högst en meter ovan vatten- och markytan. Uppe i sprickan ser man, hur hela det undre lagret skilt sig från det övre genom insipprande och utlösande vatten, varefter det nedfallit och splittrats i större och mindre block, vilka nu ligga häftade vid varandra och i mellanrummen givit upphov till alltmer förstorade håligheter Nederst kan man med strålkastare följa långa låga grottor ett tjugotal meter östlig riktning.

På gränsen mellan den våta och torra delen av grottan ha tidigare några stora stenar fallit ned, och detta förhållande utmärker hela grottsystemet, vilket faktiskt är uppbyggt på och av dylika, mestadels avlångt fyrkantiga stenblock Ytan är ojämn och raspig. Fossil sticka ut som hårda glasbitar eller smärgelkorn samt utgöra ett besvärligt och allvarligt hinder vid allt framträngande (bl. a. kalkalger, krinoidéer och koraller). Häri skilja sig dessa grottor helt från de skånska kritgrottornas jämna, om än belemnitbesatta, väggar och snirklade travertinbildningar samt Jämtlands och Lapplands släta eller i marmorkalken mjukt fasettslipade grottväggar.

Rikedomen på droppstenar är på vissa håll mycket stor, särskilt i den inre grotta, som kallats »Kapellet», och de uppvisa stor variation. Där finnas över 30 cm långa glasrörliknande stalaktiter och lika långa grövre stalagmiter, upp till 20 cm breda, längre och kortare, hela eller fläkta draperier samt betydande sinteröverdrag. De flesta droppstenar äro gulvita, men de uppträda även färgade i brunt, gult, svart och blått. Kalkspat förekommer också i stora fria kristaller, och f. ö. återfinnes både aragonit och gipsliknande utfällningar. Snövita drivor av lös kalksinter ser man i de flesta breda uppåtgående sprickor. Insipprande vatten har således upptagit icke blott atmosfärisk eller biologisk kolsyra utan av mineralförekomster och ruttnande växtlighet ibland blivit något sulfat klorid- eller nitrathaltigt.

Om det insipprande vattnets verkningar på detta sätt uppenbaras, torde dock det genomströmmande vattnet utgöra den viktigaste faktorn vid grottornas u formande. Nivåskillnaden mellan havet och utloppsgrottan är 20 m, men d erjordiska vattnet har samma betydande fallhöjd, ty det är ytterligare 20 m det österut liggande Stora Slukets nivå. Under senaste regnfattiga som- (1959) understeg utloppsmängden aldrig 5 l/sek. trots att den övre åfåran sina slukhål var uttorkad. Nederbörd brukar märkas först efter omkr. fem nar. Djupet i kanaler och grottsjöar växlar mellan 0,5 och 6 m samt håller adels omkr. 2 m. Tydliga trösklar finnas mellan de olika grottorna.

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[8] Leander Tell, Underjordens vackra värld, Stockholm 1955, Grottorna i Lummelunda och e nyupptäckt karstområde på Gotland (årsskriften Sveriges Natur), Stockholm 1956.

attnet, som vid inloppet, särskilt vår och höst, medför stora mängder detri- sand, jord, ag m. m. samt har en efter årstiden växlande yttemperatur, är utloppet alltid klart och kallt, i regel mellan + 4 och + 6 gr. C, varför det olikt passerar stora naturliga filter samt betydande underjordiska magasin. lys[9] har visat, att vattnet 120 m in i grottan innehåller 455 mg/l lösta fasta en, varibland 282 mg bikarbonat och 120 mg kalcium, varför man kan förut-, att den kemiska utlösningen avsevärt överstiger tänkbar mekanisk evor- Ett tecken härpå är bl. a. den överallt i gångar, på terraser, i sprickor och ner rikligt förekommande röda, klibbiga leran.

enna erosion har nödvändigtvis skapat stora håligheter inuti kalkplatån, de nu kända grottorna torde utgöra endast en ringa del. För att underlätta ningen, men framför allt i syfte att bereda alla intresserade tillfälle att se naturfenomen, uppdrog ett gotländskt konsortium åt förf. att sommaren leda arbetet att medels sprängning upptaga en tunnel i sydvästra berg- in till den tredje grottsalen utifrån räknat. En omkr. 58 m lång bekväm el, på ett tröskeldjup av 3,6 m eller 2 m ovanför den inre vattennivån, le- nu direkt in till sevärda droppstenpartier och egendomliga blockanhop- ar mellan mörka vattenspeglar.

nder detta arbete fick man bekräftelse på att erosionen huvudsakligen gått i ett lager revkalk. Detta synbarligen mera lättlösliga lager är icke endast - och underlagrat av den svåranfrätta märgelstenen utan på sidorna om- av en mycket hård, tung och svårlöst kristallinsk kalksten bestående av hopfiltade fina vita och röda koraller, som tydligen utgjort den yttre våg- nde kanten på ett korallrev. »Grottkalken» utgöres istället av sedimenten i en stilla lagun. Man torde därför här ha att göra med en regelrätt atoll- ning och icke enstaka uppdykande »körtlar» eller »ansvällningar» av rev- enligt äldre uppfattning.

an kan gentemot Chabot (op. cit.) även framhålla, att man i detta jäm- sevis tunna silurlager på 8—10 m i genomskärning kan iakttaga de flesta e karstfenomen, som ofta uppträda i bergarter från jura och krita. Utfors- let av denna underjordiska värld har icke heller varit lättare eller mindre yllt än framträngandet i några av kontinentens största grottor.

Hinricsson, Om halten av bakterier och vattnets karaktär i de nyupptäckta delarna av nelundagrottan, Gotland (Geol. Fören. Förhandl. bd 77, h. 4), 1955.

Belemnella Casimirovensis (Skolozdroẃna, 1932) as Indication of Upper Maastrichtian (Senonian) Beds at Meudon

By

F. Brotzen & T. Birkelund

In the paleozoological department of the Riksmuseum in Stockholm, among old collections of belemnites from Meudon in France, is a specimen (fig. 1) of Belemnella casimirovensis (Skolozdrowna, 1932). It shows a close resemblance to the type of the species from the uppermost Maastrichtian of Poland (locality Kazimierz) figured by Jeletzky (1951, pl. 6, figs. 4 a—d) and the specimen from the uppermost Maastrichtian of Stevns Klint (Denmark) figured by Birkelund (1957, pl. 6, figs. 4 a—c). The guard is 80.3 mm long and shows the ornamentation on the surface as well as the S-formed course of the bottom of the ventral fissure characteristic of the species. The distance be-

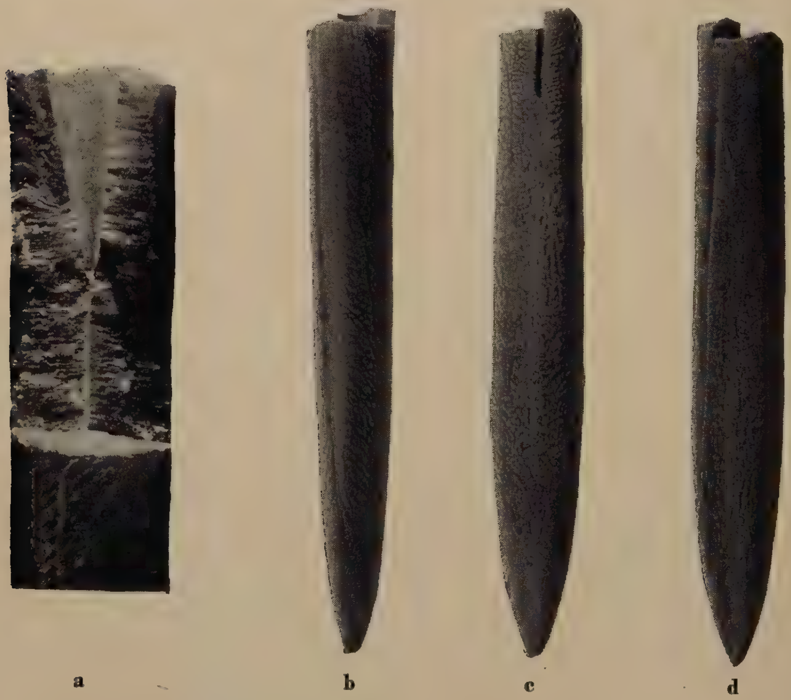

Fig. 1: Belemnella casimirovensis (Skolozdroẃna, 1932) from Meudon. **a**, lateral view of the longitudinally split anterior part of the guard showing the alveolus and the bottom of the ventral fissure. × 2; **b**, lateral view; **c**, ventral view; **d**, dorsal view; b, c, and d about natural size.

en the beginning of the ventral fissure on the wall of the alveolar cavity and anterior end of the protoconch is 4.3 mm.

pper Maastrichtian beds containing Belemnella casimirovensis are rather nsive in Russia and Poland, whereas such bed are rare in Westerns and tral Europe. Thus, in Western Europe, Belemnella casimirovensis beds e only been found in Denmark (Upper part of Stevnsian) and in the astricht area (Md).

part from the fact that the words "Meudon, France" are written on the l belonging to the above mentioned guard, no information is given regard- horizon and locality as is often the case with old collections.

s, however, this species is known from very few localities in Western and tral Europe it is likely that the locality is correctly indicated.

n the area of Meudon the Campanian and the Lower Maastrichtian is wn in outcrops. The present specimen indicates that also the uppermost astrichtian can be represented in this area.

t would be of great interest if our French colleagues could give further ticulars about finds of this index fossil in Central France.

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K/Ar Age of Biotite, Sanidine, and Illite from Middle Ordovician Bentonites at Kinnekulle, Sweden

By

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INTRODUCTION

Bentonite beds occur in the fossiliferous Middle Ordovician limestones and shales at Kinnekulle, Sweden. During World War II these bentonites were quarried by the Skånska cement company, near Mossen (Fig. 1), and the dated samples came from the face of an adit driven into a point where the bentonites are completely unweathered.

Biostratigraphic control on this horizon is excellent (Fig. 2); the Chasmops series of the Caradocian at Kinnekulle includes both shaly and shelly facies fossils (Westergård, 1943; Thorslund, 1948). *Dicranograptus clingani,* a standard zone graptolite, occurs in black shale three metres above the Kinnekulle bentonites (Thorslund, 1948); less definitive trilobites, ostracods, and graptolites occur in and below the bentonites. Thorslund concludes that the bentonite layers at Kinnekulle occur in the Lower Chasmops series of the Caradocian, above the zone of *Nemagraptus gracilis,* below the zone of *Dicranograptus clingani,* probably in the *Diplograptus molestus* zone. Recent work by Berry (1960) on the shelly facies and Dean (1960) on graptolites has strengthened the correlation between the Ordovician of Sweden and the type Caradoc series in England and Wales.

The Paleozoic beds at Kinnekulle comprise a flat-lying autochthonous series overlying the Precambrian. The section is a thin or compressed one; the Cambrian-Silurian is only 200 metres in thickness. It appears unlikely that these beds have ever been deeply buried or metamorphosed. Kinnekulle is at present capped by a post-Silurian (possibly Permian) diabase sill which lies 100 metres above the bentonite beds. The sill did not metamorphose the bentonites for the "B" ash horizon at Kinnekulle is still a swelling, montmorillonite-rich clay.

The bentonite beds at Kinnekulle are comprised mainly of illite and montmorillonite "mixed-layer" clays (Byström, 1956), but contain a silt or grit fraction that yields three minerals, sanidine, biotite, and zircon, that can be dated with some confidence (Table I). Sanidine, biotite, and illite from Kinnekulle have been dated using the potassium-argon method. The biotite could be dated by rubidium-strontium and the zircon by the uranium-lead method (Edwards *et al.,* 1959), but these checks have not yet been made by the writers.

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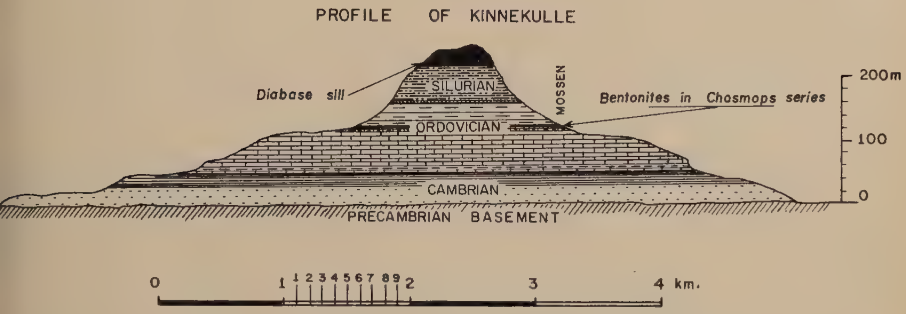

Figure 1.—West-east profile of Kinnekulle from Råbäcks harbor to Gössäters railway station, showing location of Mossen adit (after Westergård, 1943).

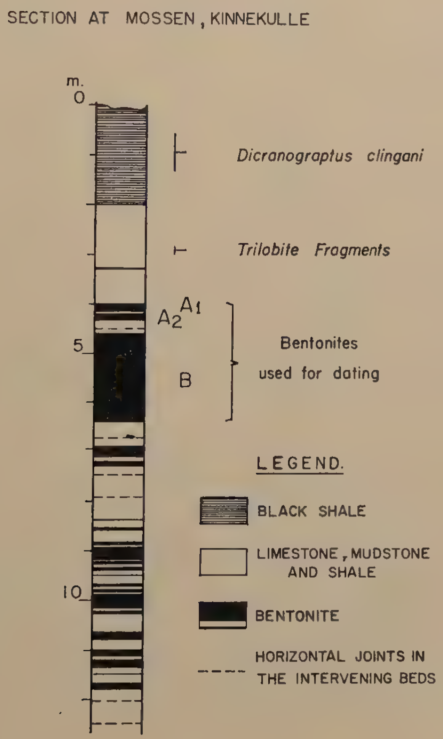
SECTION AT MOSSEN, KINNEKULLE
m.
0
5
10
Dicranograptus clingani
Trilobite Fragments
A1
A2
B
Bentonites used for dating
LEGEND.
BLACK SHALE
LIMESTONE, MUDSTONE AND SHALE
BENTONITE
HORIZONTAL JOINTS IN THE INTERVENING BEDS

Figure 2. Bentonite beds in Chasmops series at Mossen, Kinnekulle (after Thorslund, 1948).

Table I. Concentration of Datable Minerals Recovered from Kinnekulle Bentonites

Bentonite bed	Biotite g/kg	Sanidine g/kg	Zircon g/kg
A_1	20	0.5	0.2
A_2	15	trace	0.013
B	20	2.5	0.015

Table II. Chemical Analyses of Minerals Recovered from Kinnekulle Bentonites and used for Age Determinations

	1. Sanidine B	2. Biotite A_1 coarse	3. Biotite A_2 coarse	4. Biotite B fine	5. Biotite B coarse
SiO_2	64.3	35.0	34.5	33.2	31.6
Al_2O_3	20.3	17.5	17.9	18.0	18.1
TiO_2	< 0.01	4.4	3.1	1.9	1.2
Fe_2O_3	0.1	3.0	3.7	2.1	2.2
FeO	—	19.1	16.7	18.5	18.1
MnO	—	0.2	0.2	0.2	0.2
CaO	0.3	0.3	0.3	0.5	0.5
MgO	0.03	9.9	12.1	14.5	15.5
Na_2O	2.67	< 0.1	0.1	< 0.1	< 0.1
K_2O	11.75	4.1	3.9	2.9	2.0
BaO*	0.8	0.2	0.3	0.1	0.1
SrO*	0.06	0.003	0.002	0.003	0.002
ZrO_2*	—	0.05	0.01	< 0.01	0.01
P_2O_5	—	0.15	0.09	0.15	0.15
$H_2O \geq 110°$ C	—	5.5	6.4	7.9	10.6
	100.3	99.4	99.3	100.0	100.3

Analysts: A. M. Byström-Asklund and V. Grundulis.

* Spectrographic determinations by the Geochemical lab., Geol. Survey of Sweden.

Notes: Except for the sanidine the analyses were made using the rapid method by Shapiro and Brannock (1956), with some modifications. The sanidine material was purified by hand-picking; coarse = grain size > 100 mesh; fine = grain size < 100 mesh.

From the thick bentonite bed B both biotite and sanidine were isolated fo the age determination; from the beds A_1 and A_2 biotites only (Fig. 2). The biotites show varying degrees of chloritization most pronounced for the B bec biotite. From X-ray diagrams an estimate can be made by comparing the intensities of the 10 Å and 7 Å reflexions from biotite and chlorite respectively The following ratios were obtained: Intensity ratio for 7 Å/10 Å-reflexions fo A_1—0.2, for A_2—0.3 and for B—1.2. Of the enriched sanidine fractions were used of varying purity. Chemical analyses of the different minerals are given ir Table II. Data from the age determinations will be given in Table III.

Results

The three biotites give dates averaging 440, and the sanidine samples date averaging 447; the overall average is 444 million years. This is in good agreement with the 447 m.y. average age of the Middle Ordovician as determined b

Table III. K/Ar Dates of Minerals from Kinnekulle Bentonites

K No.	*Horizon*	*% K_2O*	*A^{40}/K^{40}*	*Date, m. y.*	*Description of Mineral*
ites (varying degree chloritization)					
82	A_1	5.37	0.0287	434	Almost unaltered flakes
77	A_2	4.43	0.0303	453	Coarse, somewhat chloritized
59	B	3.48	0.0288	434	Strongly chloritized flakes
	Average biotite date			440 ± 20 m. y.	
dines (varying purity separation)					
61	B	10.96	0.0304	455	Sanidine (and illitic aggregates)
90	B	11.16	0.0296	445	
146	B	12.08	0.0292	440	Pure sanidine
	Average sanidine date			447 ± 20 m. y.	
(whole bentonite, less biotite)					
69	A_1	4.94	0.0213	331	Illitic clay, trace sanidine

K_2O analyses by A. Stelmach

Constants: $\lambda_e = 0.589 \times 10^{-10}$ yrs^{-1}., $\lambda_\beta = 4.76 \times 10^{-10}$ yrs^{-1}.

$K^{40}/K_{normal} = 0.0118_1$ atomic per cent

vards *et al.* (1959) using the U^{238}/Pb^{206}-method on zircons separated from
ddle Ordovician bentonites of the Appalachian area (Adams et al, 1960).
The illite at Kinnekulle yields an age of only 331 m.y. Probably this fine-
ined clay mineral leaks argon by diffusion; possibly the illite did not form
nediately after deposition, but many millions of years later by base ex-
nge; there might have been a late Paleozoic rise in geothermal gradient as-
ated with the intrusion of the diabase sill which affected the illite though
or to a lesser degree, the biotite and sanidine. This latter seems unlikely.
t is possible that the 444 m.y. date for Kinnekulle is low. It is significant
the Sr/Rb age of the Middle Ordovician bentonites of the Appalachian
averages 475 m.y. (Adams, *et al.*, 1958) and that Holmes (1959) accepts
475 m.y. figure in his revised time scale. Kazakov and Polevaya (1958)
obtain ages of 445, 450, and 455 m.y. for glauconites from unmeta-
phosed Middle Ordovician sandstones in Estonia, a good agreement for
erials stratigraphically equivalent to the Kinnekulle beds and which occur
similar geologic environment. However, glauconite ages are generally low
linsbee, Baadsgaard and Lipson, 1960).

Conclusions

he bentonite beds at Kinnekulle occur in a favourable geologic setting, and
considerable promise as a source for minerals that may be dated absolutely.
average K/Ar age date of 444 m.y. for the Middle Ordovician (Chasmops
s of the Caradocian) may be low; it seems unlikely, however, that other
dle Ordovician sediments will be found to give higher potassium-argon

ages. Strontium-rubidium and lead-uranium dates are needed as checks before these data can be used for time scale purposes with any degree of confidence.

Acknowledgements

The potassium-argon dating project at the University of Alberta has been supported by the Geological Society of America through the Penrose fund, by the National Research Council of Canada, the Geological Survey of Canada, and the University of Alberta Research fund. Samples were collected through the courtesy of the Skånska Cement Company Ltd, Hellekis, Sweden, and were separated in the Geological Survey of Sweden laboratories, Stockholm, in cooperation with the Mineralogical Department of the Natural Museum, Stockholm, head Prof. F. E. Wickman, to whom our thanks are due for the incitement of the first separation.

All this assistance is gratefully acknowledged.

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Recensioner

Lexique Stratigraphique International. (Congrès Géologique International. Commission de Stratigraphie). Vol. I. Europe. Fasc. 2c: Suède-Sweden-Sverige. Sous la direction de Nils H. Magnusson. Utg. genom Centre National de la Recherche Scientifique. Paris 1958. 498 s. 1 karta (i 2 blad) över Sverige, 1 karta över Skåne, 2 tab. å utviksblad. Pris c. 25: — kr.

en proposition till XI. Internationella Geologkongressen i Stockholm 1910 fram-
professor L. Waagen, Wien, förslag om utgivandet av ett internationellt stratigra-
t lexikon avsett att omfatta fem band. Waagen drog upp riktlinjerna för hur lexiko-
borde utarbetas, framhöll det stora värdet av ett verk av denna art samt erbjöd
att svara för Österrike och ev. redigera bandet Europa. Som representant för Sve-
i den kommission, som tillsattes för ändamålet, ingick A. Hennig. Vid kongressen
anada 1913 uttalade sig kommissionen för, att manuskripten till bandet Europa
le föreligga 1 jan. 1915 och till hela verket två år senare. Första världskriget kom
tet att avstanna, under mellankrigsåren gjordes en hel del, bl. a. i Sverige, men
igheter av olika slag — säkerligen inte minst ekonomiska — mötte företaget. 1937
orterade Waagen till kommissionen, att manuskript färdigställts för 17 länder i
opa. Asien var i stort sett avslutat. 1938 utkom ett särskilt lexikon för Afrika och
ma år ett liknande för U. S. A. Efter ett ånyo påtvunget avbrott genom andra
dskriget reorganiserades kommittén vid geologkongresserna i London 1948 och Al-
1952. Projektet, som dragit ut över decennier, kom nu äntligen att realiseras. I
utning till kongressen i Mexico 1956 förelåg de första delarna i tryck. Utgivandet
erket har därefter fortgått i snabb takt — man nödgas nog konstatera i delvis
ör snabb takt — så att lexikonet utan att ännu vara fullständigt f. n. intar avsevärt
än en hyllmeter.

ill grund för en viss del av det material, som redovisas i Sverige-volymen, torde
artiklar, som utarbetats av Alvar Högbom (väl företrädesvis prekambrium), A.
Vestergård (kambrium) samt E. Granlund och H. Munthe (kvartär) och slutligen
enzén (sannolikt enstaka artiklar). Deras namn finns på bokens titelblad men ej
eller i ett mindre antal fall under artiklar inom deras resp. områden. Artikelför-
are är i övrigt P. H. Lundegårdh, N. H. Magnusson och E. Åhman (prekambrium);
exell (kambrium); V. Jaanusson, P. Thorslund och T. Tjernvik (ordovicium); J.
ede (silur); O. Kulling (kaledoniska bildningar); M. Beyer, F. Brotzen (meso-
um); G. Lundqvist, J. Lundqvist, R. Sandegren (kvartär). En inledande kort över-
över Sveriges geologi har författats av N. H. Magnusson.

m värdet av lexikonet kan endast råda en mening: Det är otvivelaktigt en rik in-
ationskälla, som kommer att anlitas flitigt både i Sverige och i utlandet. Samti-
ligger det i sakens natur, att källan vid enstaka tillfällen kanske inte är alldeles
allklar. Påståendet må motiveras genom hänvisning till några inadvertenser, som
älaren lagt märke till.

198 förekommer en tabellarisk översikt, som uppgives vara efter Troedsson 1951.
r endast delvis fallet. I kolumnen »Central Scania» ekvivalerar Troedsson (s. 269)
ksvis Brandsberga-blocken med katslösaetagens yngsta zon. Så står även i lexiko-
text s. 198, men tabellen låter närmast förstå, att ifrågavarande block bör inplace-
nera generellt i katslösaetagen; frågetecknet i Troedssons tabell har här bortfallit.
dsson jämnställer de undre hälsingborgslagren med resp. höörsandsten och -ar-
Thaumatopteris-floran och sandstenen med *Cardinia follini*. I lexikonet finner

man sistnämnda sandsten jämte höörsandstenen angivna såsom motsvarande övre hä singborgslagren. Artikelförfattarens mening är självfallet, att undre hälsingborgslagren skall föras till lias α, men tabellen visar något annat. I st. f. den rätt kryptiska beteckningen »*Exp. aequiv.* zone», som övertagits från Troedsson, borde stå »Z. of *Ptychomphalus expansus* and *Pseudopecten aequivalvis*».

S. 231 läser man, att rätiska avlagringar är inskränkta till västra och sydvästra Skåne för att i slutet av artikeln (s. 323) inhämta att blottningar finns även norr om Ystad, vilket ju är förhållandet. Däremot ligger inte Kågeröd söder om Hälsingborg (s. 171) utan snarare öster därom. Kolbrytningen i Skåne började inte på 1700-talet (s. 194) utan åtminstone ett sekel tidigare. Angelin 1862 (s. 321) är en referens utan täckning. Den åsyftade texten till A:s geologiska karta över Skåne utkom ju 1877, även om tryckningen påbörjats redan 1862.

Motstridiga uppgifter lämnas å s. 198, där limbatakalksten uppges förekomma inom alla paleozoiska distrikt i landet, och s. 272, där ortocerkalkstenen i Skåne förmodas vara yngre än limbatakalksten.

Något trilobitsläkte *Bailiopsis* (s. 112) är ej känt. I st. f. *Baliopsis impressa* skall stå *Bailiella i.*

Vissa artiklar har icke ägnats nödig språklig omsorg. Stundom är engelskan dålig intill obegriplighet:

»Before it was possible to separate from the Liassic keep the Rhaetic in the coal bearing beds in the southern part of country, these beds were comprehended under the designation 'Rät-lias'» (s. 163). — »Angelin — introduced the name Höganäs formation (=Höganäs series Troedsson, 1951) it as a whole for the Liassic as well as for the Rhaetic (=Infra-Lias) part of the same sequence» (s. 194). Detta är två exempel bland många.

Ett ombrytningsfel torde föreligga i inledningen till »Nemagraptus gracilis zone» (s. 247). Korrekturfelen är otaliga, något som man inte heller kan lasta författarna för i nämnvärd grad på grund av den alltför korta tid, som stod till buds för korrekturläsning, men som ger ett mer än lovligt vårdslöst intryck.

Författarna har genomfört sina uppgifter med något växlande grad av grundlighet. Vissa områden är påfallande mycket utförligare behandlade än andra. Ett, som ej alls berörts, är de paleozoiska eruptivbergarterna, som nog lämpligen kunde ha medtagits (kinnediabas, kongadiabas etc.).

Sammanfattningsvis måste dock upprepas, att lexikonet, trots vissa brister, är en förträfflig produkt.

G. Regnéll

W. H. Emmons, I. S. Allison, C. R. Stauffer, G. A. Thiel: Geology: Principles and Processes, 5th ed. McGraw-Hill Book Company, Inc. New York, Toronto, London 1960. 491 s., talrika textfig. Pris 62:— kr.

Emmons lärobok i allmän geologi utkom första gången 1932. Nya upplagor har följt 1939, 1949, 1955 och 1960. Detta tyder på att arbetet har kunnat hävda sig väl inom det rika urvalet av böcker i genren.

Den senaste upplagan visar en ganska genomgripande omgruppering av stoffet gentemot den närmast föregående. Framställningen har otvivelaktigt vunnit i överskådlighet och följdriktighet härigenom. Till den ökade överskådligheten och det allmänt angenäma intryck, som volymen gör, bidrar även nytt större format, helt ny typografi med dubbelspaltiga sidor och en genomgående make up av det redan förut goda bildmaterialet. Texten har varit föremål för en så grundlig bearbetning och modernisering, att stora partier verkar nyskrivna. De till varje kapitel hörande för-

ningarna över lämplig kompletterande litteratur har i de flesta fall utvidgats.
förefaller att vara väl avvägda men omfattar praktiskt taget uteslutande ameri-
sk litteratur. I denna upplaga har tillkommit ett glossarium, omfattande 18 si-
, som ger korta definitioner av ett stort antal begrepp och termer.
4 uppl. fanns tre appendices, nämligen ett behandlande topografiska kartor och
kturkartor, ett andra behandlande kartsymboler, profiler etc., och ett tredje be-
dlande den geologiska tidsskalan. Av dessa har det sistnämnda bortfallit genom
motsvarande stoff överflyttats till huvudtexten. De två förstnämnda finns kvar.
dem har fogats ett appendix (ganska överflödigt) med alfabetisk förteckning
r kemiska symboler för de viktigare grundämnena samt ett appendix innehål-
le en summarisk bestämningsnyckel till bergarter.
oken kan rekommenderas som god och intresseväckande introduktion till den all-
na geologin.

G. Regnéll

Hans P. Rechenberg: Molybdän. Die metallischen Rohstoffe. Band 12. Stuttgart 1960. VII + 128 Seiten. 11 Abbildungen und 13 Tabellen. Ganzleinen DM 27: —.

edan tiden före första världskriget har molybdenets användningsområde i hög grad
ats. Framförallt som legeringsmetall inom stålindustrin har dess egenskaper stor
delse, då de främjar hårdhet, seghet, värmebeständighet och viktsparande. Men
inom färg- och glasindustrin utnyttjas molybden, liksom vid tillverkning av
rolja och konstgödsel. Glödlampor, radiorör, kvicksilverlampor och elektriska
r är andra exempel på metallens användbarhet. Självfallet är molybden ett vik-
råämne inom rakettekniken.
enna så markant ökade betydelse av molybdenet återspeglas i omfånget av det
utkomna och av *H. P. Rechenberg* författade molybdenbandet i serien »Die me-
schen Rohstoffe», som har ett med 100 % ökat sidantal jämfört med den av
rusch 1938 skrivna föregångaren. Särskilt den allmänna delen omfattande 47
är kraftigt påbyggd (hos *Krusch* 24 sidor). Dispositionen tycks i stort sett vara
amma som i tidigare band, förmodligen dirigerad av en sträng redaktör. Efter
ammanfattande inledning över molybdenets kemiska och fysikaliska egenskaper
görs i kapitlet »förekomstsätt och uppkomst» för Mo-mineral, genesis, geokemi
prospektering. I mineralogiavsnittet påpekas molybdenglansens ekonomiskt domi-
nde ställning. Wulfenit har endast lokal betydelse. Men även mer sällsynta och
m. tvivelaktiga mineral radas upp. Dock utan att göra anspråk på fullständig-
Så saknas de H_2O-haltiga uranmolybdaterna umohoit, priguinit och moluranit.
ittet över prospekteringsmetoderna behandlar något mer utförligt de geokemiska
igheterna. Kapitlet om utvinningen uppdelas i avsnitt som dryftar brytningsme-
, provtagning, anrikning och metallurgi. Den allmänna delen avslutas med sam-
attningar över användningsområden, kemiska undersökningsmetoder, historik, pris-
ing och marknad, förråd och framtidsutsikter, samt den obligatoriska statistiken.
m serien i övrigt ligger tyngdpunkten på den regionala delen. På 80 sidor be-
las de 32 länder, där Mo-fyndigheter är kända. Fyndigheterna beskrivs i all-
het mycket summariskt i geologiskt, mineralogiskt och ekonomiskt avseende. För
ifterna från öststaterna gäller samma osäkerhet, som av referenten påtalades vid
sionen av *F. Ahlfeld:* Zinn und Wolfram (GFF, 1959, sid. 417). De geologiska
ifterna kompletteras endast sporadiskt med geologiska kartor (3), schematiska
ler (2) och en blockbild.
rige-kapitlet (1 sida) har i det närmaste ordagrant övertagits från *Kruschs* bok.
rr även med de ej fåtaliga sak- och stavfelen. Uddgruvan, som ju endast bröts

under första världskriget, är enligt detta fortfarande landets största Mo-tillgång. Gru vans geologi beskrivs med delvis oklar formulering. Hörken omnämns endast i förbi gående tillsamman med några mer obetydliga fyndigheter. Molybdenglansen skulle där uppträda i »granitskarn». I den *Kruschska* förebilden står dock riktigt nog gra natskarn. Förvanskningar av lokalnamn som »Ljusnorser Grube» för Ljusnarsbergs gruvan, »Kellingberger Grube» för Killingsbergsgruvan vid Bredsjö, »Leya-Grube be Guldsmeds-Hückau» för Lejagruvan vid Guldsmedhyttan, »Bremmos-Grube» fö Brännmossgruvan vid Lundsjön, »Eckholmen bei Westervik» för Ekholmen vid Väs tervik bör rättas. Det är oklart om »Grantor-Grube» i Västanforsfältet, som ej finns omnämnd i svensk litteratur, är identisk med fältets Stribergsgruva som innehålle MoS₂-impregnerad järnmalm. Existensen av »Vogbotten-Grube südlich Ludvika» ha överhuvudtaget ej kunnat verifieras.

Avsnitten i den allmänna och regionala delen avslutas med litteraturförteckningar. Sverige-uppgifterna tycks vara hämtade huvudsakligen från nordamerikanska publikationer. De viktigaste svenska källorna är icke citerade, såsom *Tegengren:* Sveriges ädlare malmer (1924), *Geijer* och *Magnusson:* Mellansvenska järnmalmernas geologi (1944), *Magnusson:* Malmgeologi (1952), samt *Ödmans* Norrbottenbeskrivning (1957). Detta ger en viss förklaring till det besynnerliga urvalet av förekomsterna.

För att vid dylika regionala sammanställningar undvika oklarheter, oriktigheter och försummelser, som ej sällan beror på språk- och andra svårigheter, vore det av stort gagn för framställningen, om författarna kunde anlita sakkunniga kolleger i respektive länder för granskning av manuskripten.

Hans J. Koark

ERHARD KÖSTER: Mechanische Gesteins- und Bodenanalyse. Leitfaden de Granulometrie und Morphometrie. Carl Hanser Verlag, München 1960. 172 sid., 38 textfig. Pris inb. 24: — DM.

Boken ger inledningsvis en översikt över jordarternas klassifikation, varvid framfö allt en sammanställning av en rad system för definitioner på de olika kornstorleksgrupperna är av värde. Den borde vara ganska användbar och ger om inte annat e god bild av den fullständiga förvirringen på detta område. Författaren själv bidra ej till att minska densamma. Som exempel kan nämnas, att på flera ställen anföre Magnusson (förmodligen N. H.) såsom svensk auktor för vissa definitioner — en uppgift som förvånar ej blott recensenten utan även N. H. Magnusson själv. Sanno likt avses Granlund eller G. Lundqvist i »Sveriges Geologi».

I de följande 3 kapitlen redogöres för olika metoder för undersökning av jordarte för provtagning och för utförandet av jordartsanalyser. Distinktionen mellan det förs och sistnämnda avsnittet är dunkel.

Härefter behandlas felkällor och grafiska m. fl. metoder för åskådliggörandet a analysresultat av skilda slag. En översikt över jordarternas geologi skall därefter g en handledning vid tolkandet av analysresultaten. Systematiken i detta avsnitt är doc oklar, såsom mycket annat i denna bok. Delvis upptages översikten av självklar fakta, utan större värde för tolkningarna, exempelvis att en flods sediment härrör frå flodens vattenområde, att deras mängd beror av flodens storlek, vattenföring o. dy

Även värdet av bokens sista avsnitt, som behandlar inredningen av ett jordarts laboratorium, är begränsat. Vissa tips kan nog erhållas, men i sin helhet är kapitle alltför översiktligt för att vara till verklig hjälp.

Sammanfattningsvis kan om arbetet sägas, att idén att ge en översikt av ämne i fråga förvisso är god. Vid arbeten av hithörande art kan man säkerligen finna mång uppslag till undersökningar. Man måste dock vara försiktig vid den detaljerade an vändningen, enär boken onekligen är behäftad med vissa brister. Detta märks t. e

anförandet av äldre arbeten av principiell natur. Författaren har i många år
at i Sverige — vilket framhålles i förordet — och borde vara väl förtrogen med
svenska litteraturen. Trots detta lyckas han diskutera t. ex. lerornas klassifika-
kornstorleksindelning över huvud taget, blockräkning m. m. utan att ens an-
Gunnar Ekströms eller G. Lundqvists ej betydelselösa arbeten i dessa frågor.
ffande blockräkningarna nämnes från Sverige endast att författaren själv ut-
några rätt obetydliga sådana. Av mer principiella arbeten av denna art anföres
ners' och Hesemanns vilka ju närmast är att betrakta som specialfall. Man måste
ga den forskare som skall försöka utföra blockräkningar med hjälp av denna
något område utanför Danmark—Nordtyskland. Han får nämligen endast veta
man urskiljer »röd östersjöporfyr» etc. etc. samt att bergarter från Finland,
nhavet, Åland och Nordsverige sammanfattas till en »Grupp I» o. s. v. Det
nförda må räcka som exempel på de brister som väsentligt inskränka bokens an-
barhet.

Jan Lundqvist

ALFRED HARKER: Petrology for Students. An Introduction to the Study of Rocks under the Microscope. Eighth edition revised by C. E. Tilley, S. R. Nockolds, and M. Black, Cambridge 1960. 283 s. och 99 fig. Pris 15 s.

mmal god årgång är visserligen ett högst meriterande attribut när det gäller
, men samma gynnsamma samband mellan lagringstid och varuvärdering exis-
ej för läroböcker. Harkers petrologibok utgavs i sitt ursprungliga skick redan
och torde därmed inta en obestridlig rangplats bland de äldsta i sitt slag. Av-
ingsmöjligheterna tycks dock förvånansvärt nog fortfarande vara goda, efter-
nu en andra omtryckning av åttonde reviderade upplagan från år 1954 ut-
nit.

n trio som efter Harkers död tagit ansvaret för revisionsarbetet har tvivelsutan
it till verket med en varsamhet, som bör tillfredsställa alla gentlemen med in-
aktning för företeelser härstammande från brittiska imperiets storhetstid. Denna
för ett svunnet århundrade kan belysas av kalla siffror, som bl. a. avslöjar
8 % (!) av samtliga litteraturhänvisningar omfattar 1800-talsstoff.

rst ges några godtyckligt utvalda randanmärkningar om mineralens optiska egen-
r, varvid bl. a. kaolin av någon outgrundlig anledning får tjäna som typexempel
paka mineral vid sidan av malmmineralen. Efter denna skäligen överflödiga
ning behandlas de olika bergartstyperna var för sig. Fem olika huvudgrupper
ıtskilts: plutoniska, hypabyssiska, vulkaniska, sedimentära och metamorfa berg-
En indelning »of convenience» enligt förf. och om med detta avses, att be-
lighet snarare än lämplighetsskäl varit utslagsgivande, finns ej något att gen-

tre första grupperna är utförligast behandlade och betraktas kategoriskt som
iva bildningar. Inte ens i form av ett understatement ges någon antydan om
raniter kan ha ett annorlunda ursprung. Däremot framgår av texten, att det
allt förekommer gnejser, som ej bildats på magmatisk väg! Oavsett klassifice-
problemen förefaller det, som om de metamorfa bergarterna blivit styvmoder-
behandlade, då de endast är tillägnade 32 av 258 sidor. Detta är desto märk-
som A. Harker spelat en så framträdande roll just inom detta område.

en med beaktande av den svåra bristen på väl avpassad kurslitteratur för det
miska lågstadiet måste denna bok anses som mindre lämplig för sådant ända-
De exemplifierande bergarterna är nästan genomgående hämtade från Stor-
nien och är intetsägande för svenska läsare på nybörjarstadiet. Den stora in-

ternationella förbistringen i namngivningsprinciper kan naturligtvis inte förf. la tas för; tvärtom har det lagts ned en viss omsorg på redovisning av tyskt och fransk språkbruk.

I en kommentar till det avslutande registret rekommenderas detta som »glossary under den motiveringen att det utvidgats med andra bergartsnamn än de som nämnt i texten. Vid närmare granskning förekommer dock inte ett enda sådant fall!

Det enda som ger ett positivt intryck är de instruktiva illustrationerna i form a tecknade mikrobilder.

Bengt Lindqvist

Mötet den 1 december 1960

ırvarande 48 personer.

rdföranden, hr Asklund, öppnade sammanträdet och meddelade följande:

en 22 november avled professor emeritus Gösta Bodman i en ålder av 85 år.
nan var född i Råneå 1875 och studerade i Uppsala, där han blev fil. kand.
, fil. lic. 1901 och fil. dr 1906 på en avhandling med titeln »Isomorfi mellan
utsalter och sällsynta jordartsmetaller». Åren 1901—03 deltog han som fysiker
meteorolog i Otto Nordenskjölds ryktbara sydpolsexpedition tillsammans med den
en avlidne professor Johan Gunnar Andersson. Han gjorde därvid en grundläg-
e insats för utforskandet av klimatförhållandena i Antarktis. Inom svensk geologi
rev han en postglacial skalgrusbank från Brandshult i Halland. Efter att ha tjänst-
som lärare och lektor vid Göteborgs högre samskola och Chalmers tekniska in-
t verkade han åren 1916—40 som professor i kemi, mineralogi och geologi vid
rande Chalmers tekniska institut. Känd har han blivit i en vidare krets för sina
riska forskningar rörande Göteborgs äldre industrier. Han gjorde en uppskattad
s vid ordnandet av den industrihistoriska utställningen i Göteborg jubileumsåret
. — Bodman var medlem av vår Förening sedan 1918.

g lyser frid över den bortgångnes minne.

phil. Otto Meier har uppvaktats med telegrafisk hälsning på 65-årsdagen den
ovember. Tackskrivelse har ingått.

ll ledamöter av Föreningen har styrelsen invalt fil. stud. Robert Lilljequist, Lund,
uens Karl-Axel Kornfält, Lund, och amanuens Hans Mårtensson, Vintrie, samt-
på förslag av hr S. Hjelmqvist.

ırefter förrättades val av styrelse och revisorer för år 1961, varvid utsågos:

l ordförande hr I. Hessland,
l sekreterare hr E. Åhman,
l redaktör för Förhandlingarna hr P. H. Lundegårdh,
l skattmästare hr O. Gabrielson
l övriga styrelseledamöter hrr B. Asklund och O. Meier.

ll revisorer att granska 1960 års förvaltning utsågos hrr J. De Geer och G. Stål-
med hr H. Möller som suppleant.

ll ledamot av redaktionskommittén efter hr P. Thorslund valdes hr F. Brotzen.

ırefter behandlades ett av styrelsen inlämnat och från föregående möte bordlagt
geändringsförslag rörande stadgarnas § 6 mom. 2. Efter omröstning godkändes
ramlagda förslaget med 36 ja-röster. 3 nej-röster avgåvos. Stadgarnas § 6 mom. 2
sålunda följande lydelse:

§ 6

— —

Korresponderande ledamöter, vilka skriftligen föreslås hos Styrel-
som efter samråd med ytterligare sakkunniga förrättar invalet. Endast utlänning
till korresponderande ledamot väljas. De korresponderande ledamöternas antal
j överstiga 25.

— —

ırefter höll hr ordföranden, professor B. Asklund ett föredrag med titeln: Fjäll-
jans randområde vid Tåsjödalen.

anledning av föredraget yttrade sig hrr B. Dahlman, T. Du Rietz, N. O. Berg-
, T. Hagerman, P. Thorslund och föredragshållaren.

d den efterföljande supén på restaurant Conti avtackades styrelseledamoten hr
romm, som avböjt omval, för ett mångårigt och fruktbärande arbete inom Geo-
a Föreningen.

Mötet den 12 januari 1961

Närvarande 34 personer.

Ordföranden, hr Hessland, öppnade sammanträdet och anförde följande:

Jag får meddela att två av föreningens ledamöter avlidit.

Den ene är läroverksadjunkten Harald Frendin i Borlänge, som avled den 5 december i en ålder av 69 år. Vid sidan av sin lärarverksamhet intresserade han sig bl. a. livligt för Tunabygdens natur och han har utgivit åtskilliga smärre arbeten på detta område. Två av dessa artiklar ingår i våra förhandlingar, nämligen en om isgropar och en om ravinbildning. Han var medlem i föreningen under 30 år.

Den andre bortgångne är förre statsgeologen professor Gunnar Ekström. Han avled den 11 januari efter en veckas sjukhusvistelse.

Professor Ekström skulle ha blivit 70 år i april. Han var född ölänning, gick i skola i Kalmar och erhöll sin akademiska utbildning i Lund. Där disputerade han 1927. Dessförinnan hade han vunnit anställning vid Sveriges geologiska undersökning. Han blev statsgeolog 1938, docent i agronomisk hydroteknik vid Lantbrukshögskolan 1935 och medlem av Lantbruksakademien 1941. Han tillades professors namn 1960.

I början av sin geologiska verksamhet kom Ekström att intressera sig för fossil och stratigrafi i Skånes kambrosilur i samband med att han biträdde vid övervakandet av vissa borrningar där under första världskriget. Långt senare publicerade han några resultat av dessa undersökningar, nämligen 1937, då han utgav arbetet »Upper Didymograptus shale in Scania». Detta utmärkes liksom Ekströms arbeten i övrigt av stor noggrannhet och tillförlitlighet.

Ekströms största insatser ligger emellertid som bekant på ett annat område, nämligen inom marklära och hydrogeologi. Hans gradualavhandling »Klassifikation av svenska åkerjordar» är jämte Atterbergs arbeten närmast efter sekelskiftet grundläggande för jordarternas klassifikation. Detta hans arbete har vunnit starkt erkännande, inte bara i Norden utan även internationellt. I sina fortsatta arbeten kom Ekström alltmer över på jordbrukets och den praktiska geologiens problem. Han har utfört ett mycket stort antal utredningar inom olika delar av Sverige rörande grundvattnet, jordlagrens genomsläpplighet, grundens bärighet och åkerjordens beskaffenhet. Han var vid åtskilliga tillfällen anlitad som sakkunnig av vattendomstolarna ifråga om erosions- och markvärderingsfrågor. Vid sin bortgång stod han mitt uppe i arbeten för Vattenfallsstyrelsen. Vidare var han sysselsatt med att fullfölja beskrivningarna till de agrogeologiska kartblad i Skåne, som utkommit under 1950-talet.

Ekström stod i sin forskning fast förankrad i verkligheten. De resultat han framlagt är i hög grad säkert grundade och vederhäftiga och torde bli bestående för lång tid framåt. Med Gunnar Ekström förlorar svensk markforskning och hydrogeologi en av sina mest framstående representanter.

Jag lyser frid över de bortgångnas minne.

Styrelsen har med adjungering av delegerade till korresponderande ledamöter kallat professor Hollis Hedberg, U. S. A. professor Roman Kozłowski, Polen, akademikern professor A. A. Polkanov, Sovjetunionen, professor A. Rittmann, Italien och professor Bruno Sander, Österrike.

Professor Hedberg är en av världens främsta oljegeologer. Han upptäckte de stora oljeområdena i östra Venezuela och var initiativtagaren till utnyttjandet av oljeförekomsterna i Kuweit vid Persiska viken. Han är känd som stratigraf och mikropaleontolog. Under årens lopp har han innehaft en lång rad representativa uppdrag. Han är bl. a. ordförande i Internationella stratigrafiska nomenklaturkommissionen och har varit president i Geological Society of America. Till helt nyligen har han varit vice president i Gulf Oil Co. och chef för bolagets forskningsanläggningar i Pittsburg. I samband med avgången från denna tjänst kallades han till en professur i geologi vid

cetonuniversitetet. Hedberg är av svensk härstamning och därmed synnerligen
:sserad av Sveriges och svensk geologi.

:ofessor Kozłowski intar en synnerligen framskjuten ställning bland världens pa-
tologer, särskilt genom sina undersökningar av graptoliternas anatomi och taxo-
i. Han har intill nyligen varit chef för polska vetenskapsakademiens paleontolo-
ı laboratorium i Warszawa, där en synnerligen livlig vetenskaplig aktivitet ägt
under hans ledning. Kozlowski har samarbetat med svenska geologer och paleon-
ger under flera årtionden och verkat stimulerande på svensk paleontologisk forsk-
.

kademikern Polkanov har under en följd av år utfört åldersbestämningar på
ı. svenska prekambriska bergarter och har därigenom gjort en väsentlig insats för
sk berggrundsforskning. Han är sedan 1920-talet sysselsatt med att utforska Öst-
lens och Kolahalvöns geologi och torde vara en av Sovjetunionens främste kän-
av prekambrisk geologi.

:ofessor Rittmann är en av vår tids förnämsta vulkanologer. Hans vetenskapliga
samhet omfattar emellertid också andra fält av de geologiska vetenskaperna. Åt-
iga svenska geologer, som haft anledning att syssla med vulkaniska processer och
arter, har haft förmånen av stimulerande kontakter med honom.

:ofessor Sander har alltid visat stort intresse för Fennoskandias geologi. Hans
nta »Gefügekunde» har funnit allt vidare tillämpning på problem inom gräns-
ådet mellan tektonik och petrografi, icke minst i Fennoskandia.

:t telegrafiskt tack har inkommit från akademikern Polkanov tillika med en tack-
else från professor Kozłowski.

yrelsen har till ledamöter av Föreningen invalt agronomerna Bo Linder och I.
tor, Jokkmokk, båda föreslagna av hrr A. Nordström och M. Moberg, vidare
nag. J. Nortio, Savonlinna, fil. lic. R. Lauerma, Otaniemi, fil. mag. I. Laitakari,
ıiemi, och fil. mag. A. Tyrväinen, Kangasniemi, föreslagna av fru Toini Mikkola
hr O. Gabrielsson, samt ingenjör B. Sundström, Örebro, och hr Roland Svensson,
kholm 50, föreslagna av hr Gabrielsson, och slutligen civilingenjör Björn Torn-
, Boliden, föreslagen av hrr F. Kautsky och T. Du Rietz samt direktör Halfdan
merfeldt Jacobsen, föreslagen av hrr O. Meier och S. G. Petersson.

irkulär nr 1 rörande Geologische Vereinigungs mötesdagar i Wetzlar den 11—13
; liksom inbjudan till Berg- und Hüttenmännische Tage i Freiberg/Sachen den
27 maj ha kommit Föreningen tillhanda. Vidare upplysningar lämnas av sek-
aren.

r Sten Florin, Uppsala, höll därefter ett med kartor och talrika ljusbilder illust-
: föredrag med titeln: Djupvik. En sälfångstboplats från sten-
erns slut och dess naturmiljö.

anledning av föredraget yttrade sig hr O. Arrhenius, fru A. M. Asklund, hrr B.
und och F. Brotzen, fröken L. Cederschiöld, fru M. B. Florin och hrr Indrigo
C. A. Moberg.

Geolognytt

Den 2 november 1960 möttes direktörerna för de nordiska ländernas geologiska undersökningar för att diskutera samarbetsfrågor. Avsikten är, att sådana möten framdeles skall äga rum varje höst. Vid det nu timade mötet upptogs bl. a. till behandling ett förslag om utväxling av tjänstemän mellan de nordiska geologiska forskningsanstalterna. Av diskussionen framgick, att tre till fem månader i många fall vore en lämplig tidrymd för besök i grannland. Dock borde de ekonomiska förutsättningarna för sådana längre utbyten närmare undersökas i samband med att enskilda utbytesfrågor aktualiserades. Däremot konstaterades, att redan nu på alla håll förelåg förutsättningar för mera kortsiktiga utbyten.

Gemensamma exkursioner i samband med karteringar i gränstrakter var ett annat önskemål, vars betydelse underströks. Vidare diskuterades utbildnings- och fortbildningsbehovet, i synnerhet för yngre tjänstemän. Särskilt framhävdes betydelsen av utlandsresor och arbete i utlandet. Man borde ställa sig positiv till dylika resor under förutsättning, att resorna på lämpligt sätt kan inpassas i det egna verkets arbetsplan. De erfarenheter, som kan vinnas vid dessa resor, borde beaktas ur meritsynpunkt vid befordringar inom de geologiska undersökningarna.

Det i förra årets sista nummer av förhandlingarna (sid. 404—406) omtalade sammanträdet i Stockholm med organisationskommittén för geologunionen hölls planenligt i Stockholm å Vetenskapsakademien den 28 och 29 december. I sammanträdet deltog J. Dons (Norge), J. Goguel (Frankrike), J. M. Harrisson (Canada), L. Hawkes (England), H. Küpper (Österrike), V. Marmo (Finland), A. Noe-Nygaard (Danmark), T. B. Nolan (USA), H. M. E. Schürmann (Holland), K. Smulikowski (Polen), T. Sorgenfrei (Danmark) samt undertecknad. N. Belyaevsky (USSR) och B. C. Roy (Indien) var förhindrade närvara. Kommittén hade även tillfälle att rådföra sig med generalsekreteraren i ICSU, N. Herlofson, varjämte E. Fromm biträdde med sekreterargöromål.

En månad tidigare sammanträdde de nordiska ledamöterna i kommittén i Helsingfors. På grundval av det ursprungliga förslaget i Köpenhamn och med ledning av de synpunkter, som framförts från de skilda staternas nationalkommittéer och huvuddelegater, utarbetades därvid ett förslag till statuter, som omedelbart utsändes till deltagarna i de kommande Stockholmsöverläggningarna. Detta preliminära förslag visade sig väl ägnat att tjäna som underlag för arbetet i Stockholm, vilket skedde i en mycket positiv anda och resulterade i att ett enhälligt förslag till statuter kunde underskrivas den 29 december.

Om geologerna ej skall behöva vänta till 1964 för en anslutning till ICSU, måst beslut om unionsbildningen föreligga senast den 15 mars. Det konstituerande mötet beräknas äga rum under andra veckan i mars. Platsen blir antagligen Paris. Hä under återges i oavkortat skick originaltexten till statuterna.

Statutes of the International Union of Geological Sciences

(Prepared by the Organizing Committee of the Union appointed by the XXI International Geological Congress.)

I. OBJECTS OF THE UNION

1. The aims and objects of the International Union of Geological Sciences are:
   - (a) to promote and encourage the study of geological problems.
   - (b) to facilitate international cooperation in geology and related sciences.
   - (c) to provide continuity in international cooperation in geology and related sciences.
   - (d) to assist the International Geological Congresses, it being understood that th long established activites of the Congresses shall be safeguarded.

MEMBERSHIP

2. Each country may adhere to the Union through either its national committee for geology, its national academy, or through another representative body of geologists appointed by the Government.
3. There shall be different financial categories of membership of the Union as codified in Article 15. Each country shall pay annually a subscription according to its category of membership. A country proposing to adhere to the Union shall specify in which category it proposes to be classed.

ADMINISTRATION

4. The work of the Union shall be directed by
   (a) the Council of the Union.
   (b) the Executive Committee.
   The Composition and function of these bodies are defined in the following articles.

THE COUNCIL OF THE UNION

5. The Council of the Union consists of
   (a) The individual representatives of the national adhering organizations, i. e. one representative for each member country, and
   (b) the Executive Committee of the Union.
   The President of the Union presides over the Council.
6. Ordinary sessions of the Council shall be called by the Council or, failing that, by the Executive Committee and shall be held every three or four years, normally at the place and date of the International Geological Congress. The General Secretary shall communicate the place and date of the session to the members of the Union and to the members of the Executive Committee at least six months in advance.
7. Resolutions from members of the Union for submission to the Council should reach the General Secretary at least four months before the session.
8. The agenda of the session of Council shall be communicated by the General Secretary to the members of the Union and to the members of the Executive Committee at least three months before the first day of the session. No question which has not been placed on the agenda can be discussed, unless a proposal to the effect be approved by not less than two-thirds of those present and voting.
9. Each member country which has paid its subscription up to the end of the preceeding year has one vote except as provided for in Article 15. The vote of each member country must be given by a representative (or deputy) nominated by that country. A Council member may represent only one member country. Decisions of the Council shall be taken by a majority of those present and voting; in the event of an equal division of votes, the Chairman shall take the final decision.
10. For special reasons, the President may, with the consent of the Executive Committee, summon an extraordinary session of the Council. He is obliged to do so at the request of one-third of the member countries of the Union.

POWERS AND FUNCTIONS OF THE COUNCIL

11. The Council elects the Executive Committee and the officers of the Union.
12. The Council has power to appoint any Committee it may deem necessary for the administrative and scientific work of the Union. The power to dissolve a committee rests with the Council.
13. The Council reviews and takes appropriate actions on the Report of the Executive Committee on the administration of the Union for the period elapsing since the previous Council session.
14. The Council examines and takes appropriate actions on the accounts for the period elapsing since the last session of the Council and discharges the Treasurer of liability. The Financial Year is the calendar year.
15. The member countries shall annually pay the contributions applicable to their financial category of membership in accordance with the following table:

Category	1	2	3	4	5	6	7	8
Units of contribution	1	2	3	5	7	9	12	15

The Council determines, on the proposal of the Executive Committee, the value of the unit of contribution. This decision is made by Council, assigning to each member country a number of votes equal to its category of membership.

16. On the proposal of the Executive Committee, the Council considers applications for membership of the Union and the adequacy of the financial category proposed. It may accept or reject the application.

17. (a) If at the end of any year a country has not paid its subscription the Executive Committee has the right to cancel the membership of the country with 12 months notice.
(b) A member country may cancel its membership with 12 months notice.
(c) Any country which resigns from or loses its membership in the Union shall forfeit all rights it may have had in the Union.

18. The Council shall consider and may ratify By-laws submitted through the Executive Committee. By-laws may be modified by a simple majority of votes at a Council Meeting. The By-laws, or any further partial or total modification of them, shall come into force at the close of the session at which they are ratified.

VI. EXECUTIVE COMMITTEE

19. The Officers of the Union shall consist of a President, four Vice-Presidents, the past President, a General Secretary and a Treasurer and shall constitute the Executive Committee.
In case of any vacancy occurring among its members the Executive Committee shall have power to fill it. Any person so appointed shall hold office until the next session of the Council which shall proceed to a definite election.

20. The members of the Executive Committee hold office until the close of the ordinary session of the Council following that at which they were elected.

21. The President is not immediately eligible for re-election to the same office. Vice-Presidents are eligible for immediate re-election to the same office once only. Other officers are immediately eligible for re-election.

22. The Executive Committee shall present a report of its activities at sessions of the Council.

23. The Executive Committee shall act on behalf of the Council between sessions of the Council.

VII. COMMISSIONS

24. The Council may entrust to a Commission the responsibility to study any particular geological field.

25. The chairman and members of each Commission shall be elected by the Council on the proposal of the Executive Committee. They remain in office until the next session of the Council and are eligible for reappointment.

26. A Commission is composed of a convenient number of members kept at a practical minimum in relation to the nature of the work of the Commission.

27. Except as otherwise determined by the Council, Commissions shall present reports of their work to the Council at each ordinary session.

28. With the approval of the Council or the Executive Committee, a Commission may issue its own publications and may entrust any part of the work to national institutions or to individuals.

VIII. GENERAL PROVISIONS

29. The Council may accept affiliation with autonomous international associations.

30. These Statutes shall come into force as soon as they have received the approval of the assembly of representatives of countries nominated in the same way as is determined in these Statutes for the composition of the Council of the Union.
No change shall be made in the Statutes except with the approval of two-thirds of the votes of the members of the Council present and voting.

31. The English text shall be considered to be the authoritative text in the interpretation of these Statutes.

Stockholm, December 29, 1960.

Original draft signed by:

J. Dons
J. Goguel
J. M. Harrison
L. Hawkes
H. Küpper
K. A. Lindbergson
V. Marmo
A. Noe-Nygaard
T. B. Nolan
H. M. E. Schürmann
K. Smulikowski
T. Sorgenfrei

Sthlm i januari 1961.

K. A. Lindbergson

Till ordförande i Nationalkommittén för geologi efter professor Nils H. Magnusson har utsetts professor Frans E. Wickman.

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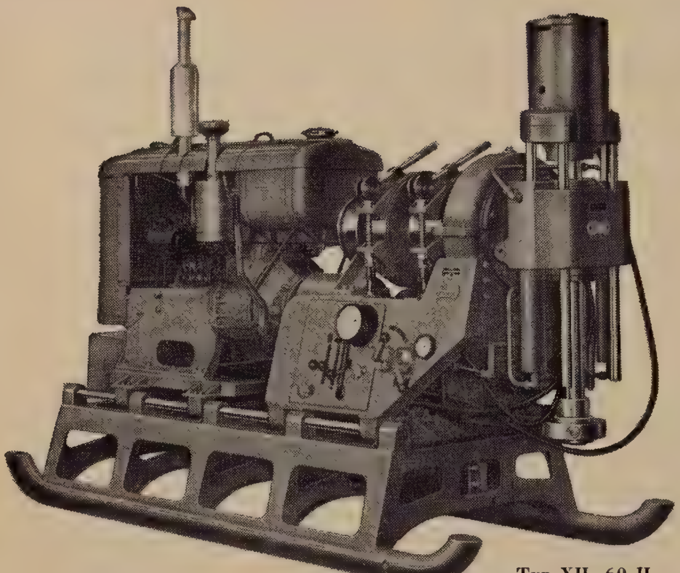

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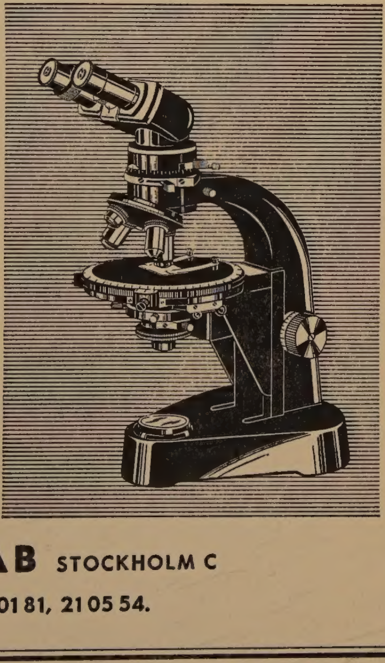

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